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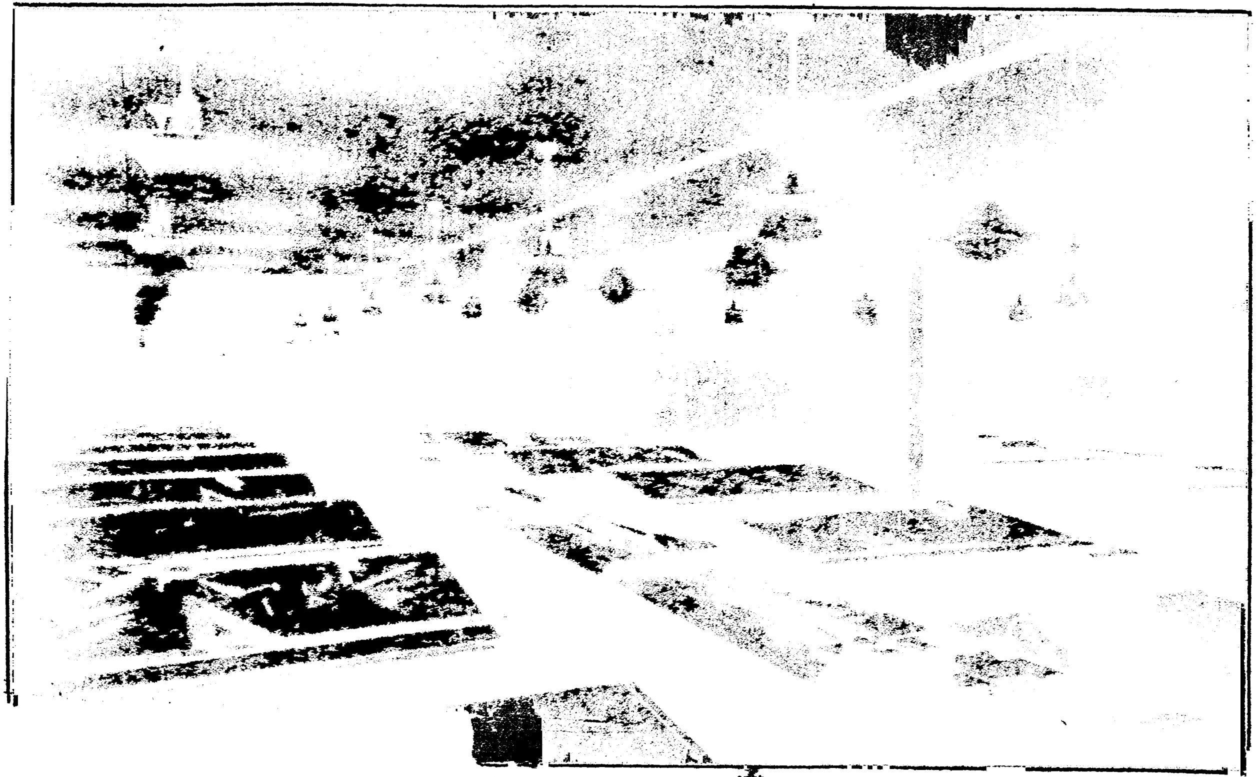

A TOOL DESIGNING DEPARTMENT

TOOL DESIGN

FUNDAMENTAL PRINCIPLES OF DESIGN AS APPLIED TO TOOLING FOR PRODUCTION

By

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425 Illustrations

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PREFACE

The tool designer is the link that connects the work of the engineering department with the production job. He needs all the practical knowledge of the expert mechanic, coupled with inventive genius. His job is that of selecting the machines and developing the tools that will produce piece parts with a high degree of accuracy and speed.

The unit cost of piece parts produced depends very largely on the skill of the tool designer. He makes the decision as to the amount of money that can profitably be invested in a tool. He must invent and develop devices for holding work and must create tools to perform the cutting operations. A skillful and ingenious tool designer will reduce, to a minimum, the number of operations necessary to complete a piece part. It is this combination of the expert mechanic, the skilled draftsman, and the inventor, that makes the tool designer one of the "key" men of modern production manufacturing.

In one sense this text is a companion text to our popular book *Tool Making* by the same author. It covers the same general field of operations, but in this new book the design of fixtures and tools is stressed rather than the methods of making them. This book has the general characteristics of all our "how-to-do-it" books: it is written in such a simple and direct style that the beginning tool designer will find valuable information and help on simple jobs, and the expert will find many suggestions to help in the ever increasing number of problems his job presents.

The outstanding feature of the text is the great number (over 425) of excellent and valuable illustrations. These have all been taken from the production field. In most cases they are actual tool designs, and therefore contain a wealth of information for the expert as well as the apprentice. The drawings have been selected to cover a wide field, and the typical designs that are presented illustrate principles that find many and varied applications in other tool designs. A thorough study of these drawings, apart from the discussion in the text, will constitute a real and practical education in tool designing. The author of this work has had extensive practical experience in designing tools. As president of a company engaged in marketing tools to supply metal-manufacturing concerns, he has had the opportunity of keeping in touch with the most up-to-date practices in this field of modern production. The author wishes to acknowledge with thanks, the valuable assistance received from various companies and from individual friends connected with these metal-manufacturing plants. He also is indebted to Mrs. F. Swarts for editorial work on the manuscript, and to Mr. A. E. Burke and the drafting room staff of the American Technical Society for work on the illustrations. It is felt that this book will fill the needs of ambitious beginners in the field of Tool Design and be of practical value in helping experienced men solve their design problems.

-DATE TOOL ROOM

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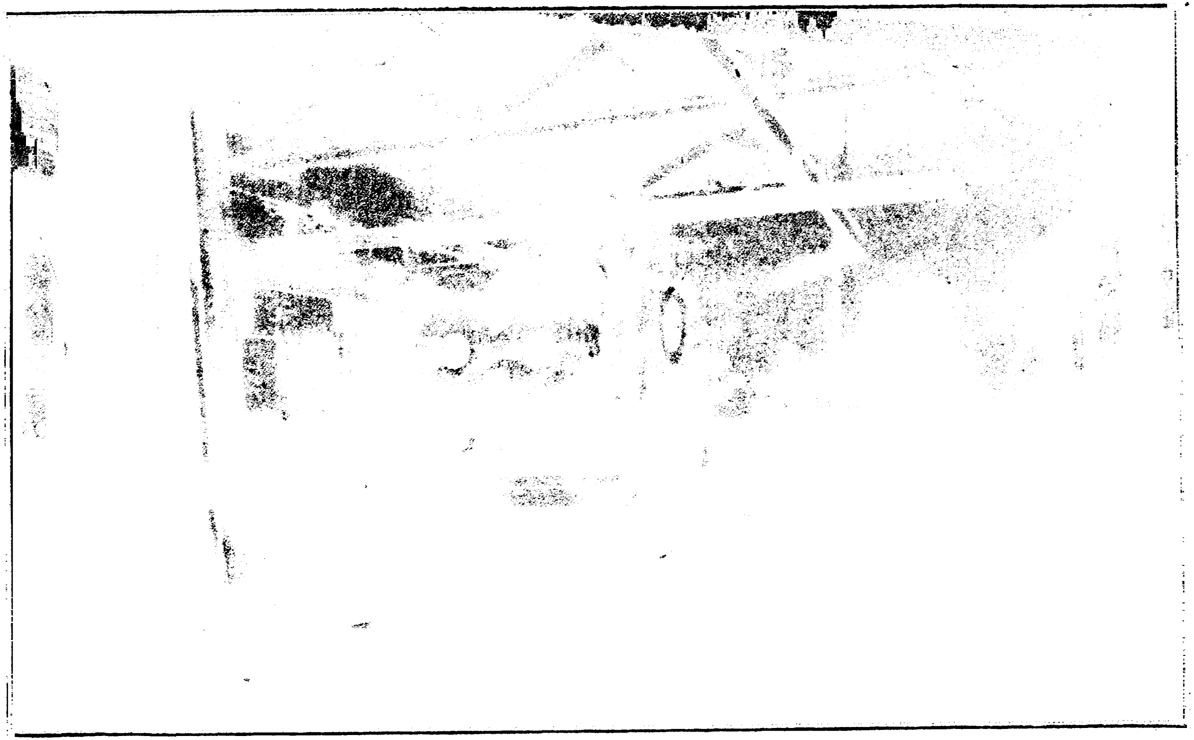

HORIZONTAL BORING MACHINE WITH ROTARY TABLE FOR MACHINING A STEEL CASTING ON FOUR SIDES WITH ONLY ONE SETUP

Courtesy of Giddings & Lewis Machine Tool Co., Fond du Lac, Wis.

TOOL DESIGN

INTRODUCTION

The Field. Tool designing has become one of the most important factors in our present industrial structure. Without tools which are properly designed and made, it would be impossible to produce many of the articles of metal, such as radios, washing and sewing machines, refrigerators, gas and electric stoves, and others too numerous to mention, which are in every-day use in our homes.

The automobile industry today could not exist without the tool engineer and the tool designer. This is also true of our railroads with their new Diesel streamliners, and it is true of great factories where modern farm machinery is manufactured. The production of the modern aeroplane is also dependent on the tool designer.

In our so-called mechanical age, particularly in the metal-manufacturing plants, there are two distinct groups of tools; one comprises **machine tools,** the other, perishable or **small tools.** They are dependent on each other. The machine tool is the only type of machinery that is capable of reproducing itself. To do this a machine tool requires small tools such as tool bits, boring bars, drills, reamers, taps and dies, jigs, fixtures, dies, gages, etc. Without the necessary small tools the machine tool cannot be used, and in most instances a machine tool is necessary to obtain the required power to operate the small tools.

During the past several years considerable improvement has been made in machine tools, due in part to the discovery of new types of steel and alloys of other metals, all much in demand for use in modern production. The use of articles made from these various metals is constantly expanding. All of this has created a demand for tool designers, so that tools can be properly designed to produce these articles at the lowest possible cost. The aim is to make these products available to the public at prices that will enable the majority to purchase them. The tool designer has been responsible for the low cost of many articles that are essential to our modern civilization.

A good all-round tool designer is seldom out of a job.

Qualifications. To become a tool designer, it is necessary to have had considerable experience in the making of tools or the use of tools in the shop. In addition, a thorough training in mechanical drawing or drafting is required, coupled with a fair knowledge of mathematics. It is also desirable to be able to make reasonably good free-hand drawings or sketches. The ability to sketch can be acquired by the study of some good book on this subject, and by practice. Many tools are designed in the drafting room from rough sketches that have been done in the shop.

The tool designer should be observant in the shop and make notes, either written or mental, of the way the tools actually operate on production. By doing so he can often make improvements on subsequent tools of similar design.

A good tool designer is an accurate one. This means that he carefully studies the part for which he is going to design a tool and selects the proper type of tool. He makes sure that all locating points are noted on the tool drawing and that his dimensions are correct, for he knows that errors mean loss of time and money. It is easy to change dimensions on a drawing, but very expensive to correct errors in metal.

A good tool drawing is always neat—never sloppy. All necessary dimensions are shown in proper location, and, where the design is at all complicated, three or more projections are drawn. The tool designer must consider that the toolmaker is not a mind reader, but is one who must convert the tool designer's ideas into metal. The toolmaker cannot make the tool properly unless the drawing clearly indicates what is required. The habits of neatness and thoroughness should be cultivated by tool designers.

In the main, the best tools are not the most complicated; therefore, the tool designer should strive to design tools that are as simple as possible. It is a known fact that the larger the number of parts to any mechanical device, the greater are the possibilities for error and trouble.

A tool designer should be well informed and have an open mind if the tools he designs are to be in accordance with modern practice. This knowledge can be obtained by reading and studying various technical books and trade magazines, or by joining some organization or society which provides opportunity to associate with men in similar positions in other plants. Thus by an interchange of ideas he can keep abreast of the latest developments in tool design. Having acquired this background of knowledge, the tool designer must use imagination and creative ability to solve problems of design, and he must develop initiative to carry them through.

ELEMENTS OF TOOL DESIGN

Over a period of years in the metal manufacturing industry, certain fundamental principles of tool design have been developed and have become standard practice. In most plants, for example, if a reasonably accurate hole is required in a part, the tool drawing of the jig shows a drilling and reaming operation. A great many former standards have been changed by reason of technical developments. For example, until a few years ago no one would make an angle plate out of anything but cast iron. Some shops still consider this the best way, but many plants now use welded steel plate.

The demands of the mass-production industries have created new developments in tool design; old clamping and holding methods have been superseded by air- and hydraulically operated jigs and fixtures. Up to the present these latter methods have not come into widespread use; therefore, this book will deal with the fundamental principles of tool design.

To design tools properly, there are a number of considerations that must be carefully weighed by the designer. They are as follows:

Tool costs are an important factor in modern manufacturing. The number of pieces or parts that are to be made per year, or total estimated requirements, will determine the cost for tools. If the number of parts to be produced is small, the tools will have to be designed and made as cheaply as possible. If a large number of parts are to be made, the designer can be allowed considerable leeway on the cost of the tools, due to the fact that the tool cost, divided among a large number of parts does not represent very much money on each individual part. For example, if tools to produce 1,000 parts per year would cost $500.00, it would mean that each part must bear a 50c charge for tools. On the other hand, if the tools which cost $500.00 would produce 10,000 parts per year, the tool cost would average only 5c per part.

The type of tool to be designed is very important. This of course depends on the machine tools available in the plant and the number of pieces or parts required, also the accuracy desired. On some parts there might be several possible designs for the tool. Usually there are only one or two ways that would be absolutely right. For example, a washer or shim is to be made of thin material, and it is desirable to have this perfectly flat. A progressive die could be designed to do the job, but the piece would probably be dished. If a compound die is correctly designed for the piece, the shim will be perfectly flat. It is essential that the tool designer use good judgment in selecting the type and kind of tools he designs.

The use of standard items is always advisable whenever they can readily be procured, as this will enable the shop to produce tools at lower cost. Do not use special bolts, studs or nuts if they can be avoided. Also, try to reduce the number of sizes of bolts and screws in designing tools. For some tools it will be observed that hollow head cap screws $\frac{3}{16}$, $\frac{1}{4}$, $\frac{3}{8}$ and $\frac{1}{2}$ inch in diameter are called for on the drawing. In many instances two sizes could be used without materially affecting the efficiency of the tool, and such elimination of extra sizes of screws will reduce the cost of the tool.

The tool designer can further reduce the cost of tools by the proper selection of material sizes. He should try to pick out standard sizes of materials from the manufacturers' catalogs or stock lists. By doing so, material can be obtained promptly, and a great deal of extra machining will be eliminated.

A complete file of manufacturers' catalogs should be maintained in the tool-designing department so that they can be referred to by the tool designer. These catalogs often prevent the unnecessary designing of special cutting tools, by reason of the fact that by referring to a catalog it will be found that a standard tool is available, or a manufacturing specialist is in a position to furnish the special tool at a reasonable cost. Many catalogs contain valuable information and data that the tool designer must know; for example, the size of bore required for an antifriction bearing. Thus, by the use of catalogs, a great deal of time can be saved and useless work eliminated.

The tool designer must keep in mind at all times that excess weight should be avoided in designing tools, and at the same time *he must give consideration to the strength required. Weak tools are easily broken and cause trouble. Tools made too heavy sometimes slow production; in addition, the excess material costs money.*

Sharp corners on tools should be avoided, particularly on jigs, fixtures, and dies, except where it is essential to the work the tool performs.

Radii and fillets should be clearly indicated on tool drawings. It is important to remember that if sharp corners are allowed on tools of high-speed steel and tool steels or on details of jigs, fixtures or dies, when they are hardened, any breakage will invariably occur at these points. In most cases a radius can be allowed which will strengthen the tool.

The safety features of tools are very important. Tools must be designed so as to prevent injury to the operator. This is particularly true of dies, especially forming or second-operation dies.

FUNDAMENTALS IN DESIGN PRACTICE

In designing tools and fixtures required to manufacture a certain part, the tool designer reviews the proposed procedure of the estimate. After the sequence of operations is determined, he consults the interested parties who will produce this part. He then starts to design the tools.

There are five major factors that must be considered when designing a tool or fixture:

1. The quantity of parts to be produced
2. The quality of the parts to be produced
3. The machine required for operation, or space available
4. Should the fixture be hand-operated, semi-automatic, or automatic
5. The viewpoint of safety to the operator

Before the tool designer proceeds to design the tool, he should obtain all necessary information in regard to the preceding operations on the piece part and the most desirable locating points. These are shown on the operation sheet or may be procured from the tool supervisor or tool engineer in the plant. When it is necessary to select rough surfaces for locating a piece part in a fixture, be sure to avoid the parting lines of the casting (this is the line or fin that is sometimes left on a casting when the mold is in two *sections (cope and drag). These parting lines are not uniform and* might cause trouble if locating points were taken on a piece part at these sections). In the event that the piece part is made of a drop forging, there will be a flash line between the upper and lower half of the drop-forging die. When it is necessary to locate a piece part on rough surfaces, and there will be succeeding operations for which tools must be designed, always select the same location points for each operation.

The tool designer should study the blueprint of the piece part carefully to be sure that he understands what surfaces are to be machined, and what relation these surfaces will bear to other surfaces to be machined on the same piece part. The tolerances specified on the piece-part drawing should be carefully analyzed to see that they are within manufacturing limits. When cored holes are used as a means of location, it is necessary to see that such locations will be satisfactory in relation to the other surfaces to be machined in later operations.

On tool drawings the name and type of tool should be put in the title block on the drawing; for example, *Milling Fixture to Mill Top Surface and Sides of Bracket.* It is sometimes advisable to insert the number of the operation. The tool should be given a number and it is advisable to give the name and number of the machine on which the fixture is to be used. If more than one certain design of piece part can be machined in the same fixture, the design numbers of these parts should be given on the tool drawing. Milling machine operation layouts should include cutter setup blocks, also spindle and cutter. These should be shown on the assembly drawing of a fixture, as should also important gaging dimensions.

In the material list, the sizes and types of material should be clearly stated; and it should be specified if the material is to be hardened. On some types of simple fixtures the assembly and detail drawings can be put on one sheet. However, where there are patterns and castings involved and numerous details, separate sheets are used. A tool drawing should specify that the tool number be stamped on the fixture. In a great many plants special alloy steels and tool steels that must be hardened and ground have the brand name or other identification name marked on them so they can readily be identified when replacements are necessary.

The word "tolerance" in metal manufacturing means that definite limits of accuracy have been established. If the dimensions of a piece part are given as a fraction (for example, 4½) it usually means that this dimension has an allowable limit of error to plus or minus .005″. In other words if the dimension on a piece part is 4½″, it could be made .005″ over, or it could be .005″ under, this dimension. On the other hand where a dimension is given as *4.500″*, this is termed a *flat dimension.* Many tool designers put dimensions on drawings in this manner; however, this is not correct because to hold a piece of work to a flat dimension of this kind would mean adding excessive cost to the machining operation. The dimension should be placed on the drawing with the tolerance, which should be as large as practicable. For example, the dimension *4.500″ plus .001″ minus .001″* would mean that the piece can be machined as much as .001″ over the basic dimension, or it can be machined .001″ less than the basic dimension.

Close limits of accuracy add to the cost in producing piece parts and are an unnecessary expense in many instances where close tolerances are not actually required. A tool designer in every case should specify the required limits of accuracy plainly.

All locating pins should be made somewhat smaller than the hole they are to enter, particularly in locating in fixtures for successive operations. These pins should be from .002″ to .005″ smaller than the hole they are designed to enter.

On dimensioning holes that are to be bored in a jig borer, dimensions should be given from a vertical surface to a vertical center line of holes, see dimension *2.875* of Fig. 1, and then from center to center of holes. The vertical dimensions are taken from a horizontal surface to a horizontal center line of holes, see dimension *1.0625,* then from center to center of holes. On all holes spaced from a central point, the radial dimensions should be given. In dimensioning drawings, make sure that the decimal points are in their proper place; failure to do this can cause considerable expense and trouble in the tool room.

In detailing, make sure that enough views of the detail are drawn so as to avoid any possible chance of confusion. In other words, these details must be definite and complete so that a tool made from the design will be as intended.

Whenever it is necessary to use a pin or a dowel, its size should be shown as a fractional dimension. The size of the hole should be given with the same fractional dimension as the pin, but with a note of *press fit* or *drive fit*. When it is necessary to use a hardened and ground part, the fit required should be added to the dimension, such as a *slip fit, running fit, drive fit* or *press fit.*

To avoid machining operations, specify, whenever possible, sizes that are standard.

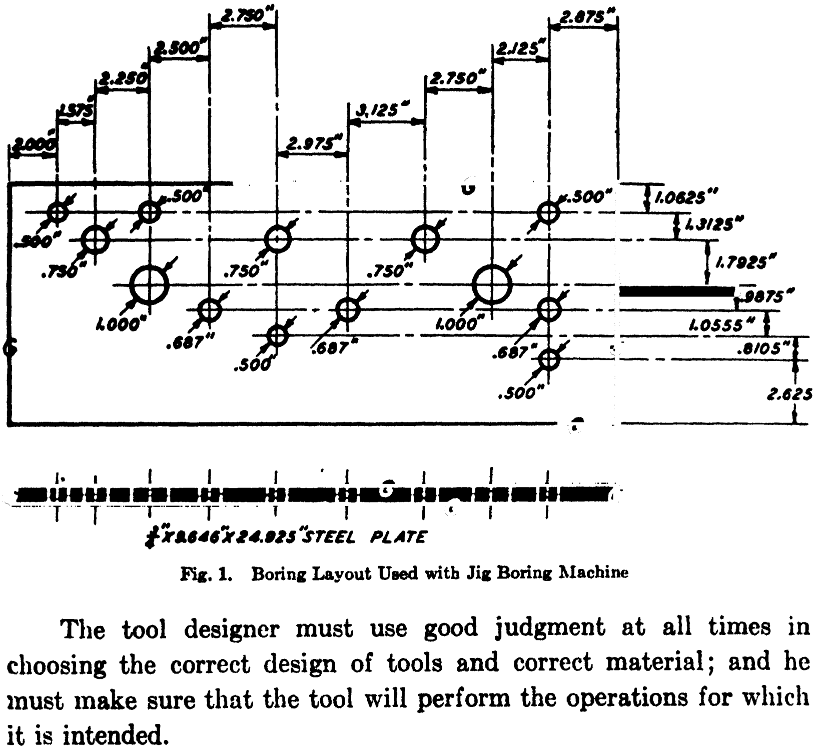

Fig. 1. Boring Layout Used with Jig Boring Machine

The tool designer must use good judgment at all times in choosing the correct design of tools and correct material; and he must make sure that the tool will perform the operations for which it is intended.

Having acquired information concerning the previous operations on the piece part, the designer studies the blueprint of the part as well as a casting of it if one is available. It is always advisable for him to consult the shop superintendent or foreman of the department in which the tool is to be used. Such a discussion of the proposed design in advance can eliminate many difficulties and make sure that the ideas of the superintendent or foreman are in accord with the designer's. This cooperation assures favorable consideration for the tool when it is put into the shop. The designer starts the layout by drawing the piece part in red, and where there is any possibility of the piece part or the tool interfering with the machine, such parts should be indicated in blue so that this interference may be avoided. Around this, a layout of the proposed tool is drawn.

Three complete views of a design should always be shown except where it can plainly be seen that the third view would be of no value to the layout or in understanding just what the designer intends. After this layout or preliminary assembly drawing of the tool is made and the design is approved, the detailing of the various parts can be finished. The final assembly drawing is made up from the checked detail drawings. By this procedure any errors are discovered when this drawing is made, thus providing a double check. In some shops no final assembly drawing is made; instead, the preliminary assembly drawing is made to serve as the complete assembly drawing.

TYPICAL MANUAL OF PROCEDURE

In a great many plants, before proceeding with the design of various tools, instructions are given to the tool designer that will enable him to handle the work in the way the plant wishes the drawings to be made. By instruction of this kind a great deal of lost time is eliminated and the tool designer has something to guide him. This avoids the necessity of going to the chief tool designer and asking needless questions.

The procedure shown is not that followed in all plants, but is fairly representative of a great many.* The instructions follow.

You are kindly requested to note the following paragraphs for simplification and standardization of tool-design work in this department.

1. You may omit the location of screw and dowel holes except in cases where the exact location must be held. Screw and dowel holes should be shown in their correct position to scale.

2. Though the title of the assembly sheet (Sheet No. 1) must be fully descriptive, as it has been the practice, the title of the detail sheets may be just "Details."

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*For various reasons, some of these standard rules could not be followed for the illustrations shown in this book. For example, title blocks, instructions, etc., have in some cases been omitted for lack of space in the drawings, which are necessarily shown reduced.

3. Detail titles shown in the part list should be confined to one word if possible. For example: pin, plug, plate, block, hub, bushing, etc.

Exceptions:

- Lower Die Shoe
- Upper Die Shoe
- Hex. Nut
- Jam Nut
- Standard Washer
- Hollow-Head Screw
- Hollow-Head Set Screw
- Hex. Head Screw
- Fillister-Head Screw
- Round-Head Screw
- Etc.

4. Leave out specification for dowel pins in "Material" column.

5. If made of steel, leave out specifications for screws, nuts and washers in "Material" column.

6. Each detail should carry its number, material, and quantity required. If part has to be hardened and ground, specify accordingly.

7. Bolt Holes

Specify clearance holes for bolts as follows:
Example: for ½" Hollow-Head Screw, 5 holes

(5) 33/64" Drill

If counterbored,

(5) 33/64" Drill & 49/64" Dia. CTB ½" Deep

In most cases 1/64" diametrical clearance will be sufficient; in rare cases 1/32" is used.

Note that the O.D. of commercial screws always runs undersize; that is, they are manufactured to a minus tolerance and will fit a hole of the nominal bolt size. For instance, a ½" bolt will go into a ½" drilled hole. But despite this fact, a hole 1/64" larger in diameter is, for practical reasons, generally used in this department.

8. Screws

When using commercial screws, use Hollow-Head Screws in place of Fillister-Head Screws. Use Fillister-Head Screws for sizes smaller than ¼".

Hollow-Head Screws can be had from ¼" up.

9. Abbreviations for Screws

- Holl.-Hd Scr.
- Fil.-Hd. Scr.
- Hex.-Hd. Scr.
- Rd.-Hd. Scr.
- Flat-Hd. Scr.
- Holl.-Hd. Set Scr.—Dog Pt.
- Holl.-Hd. Set Scr.—Cone Pt.
- Holl.-Hd. Set Scr.. —Cup Pt.
- Holl.-Hd. Set Scr.—Rd. Pt.
- Sq.-Hd. Set Scr.

10. Dowel Holes

Call for dowel holes as follows:

(2) ⅜" Ream for Dowel

When doweling two or more parts together, it is sometimes necessary to have a press fit for the dowel pin in only one piece, to insure the pin staying in that piece while disassembling the fixture. In that case, call for

(2) ⅜″ Ream—Pr. F. for Dowel

on the part with the smaller hole and

(2) ⅜″ Ream—Push Fit for Dowel

on the part with the larger hole.

When dowel holes have to be located from other parts, call for

(2) ⅜″ Ream—Pr. F. for Dowel
Loc. from Det. #6

11. Thickness Gages

For sheet steel and steel plates use U. S. STD. GAGE.
For strip steel and spring steel use BIRMINGHAM GAGE.
For music wire use MUSIC WIRE GAGE.
For steel wire use AMERICAN STEEL & WIRE CO. GAGE.
When specifying, give number, decimal and name of gage. Example:

#16 (.062) U. S. S. GAGE

12. Detail Drawings

a) When detailing, show the parts in the same position as they are shown in the assembly whenever possible.

b) To simplify detail work you may use a small sheet, put same on top of the assembly drawing and trace the details. The smallest sheet to be used is Works Form #351, except when assembly is made on sketch size sheet.

c) Details must have over-all dimensions.

d) Show center lines on round pieces.

e) In many cases considerable savings can be made by avoiding even over-all dimensions, provided they represent machining dimensions. For example, do not make a piece which has to be machined on the outside.

2″×2″×2″ if it can be made

1⅞″×1⅞″×2″

For the 2″×2″ size, 2½″×2½″ stock may have to be used, and ¼-inch will have to be machined off on each side.

For the 1⅞″×1⅞″ size, 2″×2″ stock can be used and only ⅛ inch will have to be machined off.

13. Relief for Grinding

Show the kind of relief required and dimension it if necessary.

When a radius is preferred to an undercut, it is better to call for a 1/16″ MAX. RAD. than merely to call for a 1/16″ RAD. In the latter case, time may be wasted in making the radius 1/16″ while the radius may be anywhere between 1/64″ and 1/16″.

14. Dies

a) *"P" Number and Make of Press*

The assembly drawing of a die must specify the "P" Number and make of press used. Give this information in the right-hand corner of the drawing on the left side of the part list.

b) *Closed Die Space*

Show the front view of the die with the punch holder at its lowest position and with the part in place. Give the dimension from the top of the punch holders to the bottom of the die shoes in the following manner:

6⅝" Closed Die Space

c) *Stock Thickness*

The thickness of the stock to be punched, sheared, or formed must appear somewhere on the drawing.

15. Limit Gages

a) Specify material for ⅛" to ⅝" thick flat limit gages as follows:

Flat Ground Stock Tool St.
Hdn. & Gr.

b) Have the words "MAX." and "MIN.", the part number, and the maximum and minimum dimensions stamped on the gage, and show their location on the drawing.

c) Decimal dimensions on gage drawings must carry "Toolmakers" tolerances.

d) Flat snap gages must be provided with a ¼" drilled hole for the purpose of hanging the gage on a pin.

CHECKING

In the majority of metalworking plants having tool designing departments, after the individual tool designer has completed his drawings of the tool to be made, the design is checked, usually by an experienced tool designer who is employed for this specific purpose. It is entirely possible that the tool designer has made errors which, in the event they were not detected, might be the cause of making a poor tool or add unnecessary expense to the making of the tool. Certain definite items should be carefully considered by the checker before he signs his name in the title block as certifying the tool drawing is correct for the purpose for which it was designed. It is well for the tool designer to know what points the checker is going to look for. The following is a composite outline of these items, and though not standard, it is typical of those used in the majority of metalworking plants.

1. Check for conformity with drafting-room standards.

A. Check size of sheet.

B. Are projections correct?

C. Are sections properly labeled?

D. Is drawing perfectly clear?

E. Is drawing neat? Are all figures plain and will the drawing make a good blueprint?

2. Check for design.

A. Is the weight of the tool properly distributed?

B. Has the tool sufficient strength?

C. Check for molding, forming.

D. Analyze the cost. (This means: is the probable cost of the tool in line with the design of the piece part and the quantities to be produced?)

E. Can it be machined? (Would it be possible to make the tool as designed?)

F. Are there any interferences?

G. Can it be assembled? (This means that a design may look feasible on paper, but perhaps cannot be transferred into metal due to machining limitations which would make it impossible to assemble the various details of the tool.)

H. Are undercuts, fillets, or chamfers properly indicated?

I. Are all bores of the correct size?

3. Check for dimensions.

A. Are all dimensions correct?

B. Does the drawing have necessary or unnecessary decimal dimensions? (The tool designer sometimes specifies decimal dimensions to very close limits where these are unnecessary and a fractional dimension would be satisfactory.)

C. Eliminate duplicate dimensions.

D. Are all arrowheads shown?

E. Are dimensions that do not scale underlined?

F. Check as to whether or not special drills and reamers are necessary.

G. Check for tap drill sizes.

H. Are all necessary dimensions shown on the tool drawing?

I. Are all necessary finish markings shown properly?

J. The details of the tool drawings should carry this note: "Remove unnecessary sharp corners." (This is very important as sharp corners that are left often cause injury to the operators who use the tools.)

4. Check title block.

A. Is the title of drawing correct and complete?

B. Check tool pattern and drawing number.

C. Is correct date shown?

D. Are signatures correct?

E. Check number of parts required.

F. Is the correct material used for the various details of tool drawing?

G. Check the operation for which the tool is intended.

H. Check the machine on which the tool is to be used. (This is important as it is sometimes found that tools are designed that are totally unsuited to the machine on which they are to be used.)

5. General notes.

A. Are all parts necessary to complete the tool as designed and detailed?

B. Are all standard or purchase parts of tools listed in the bill of material?

C. Are chucking rings or machining lugs necessary on the various details of the tool?

D. Has the proper material been specified and is it readily available; also check to see whether the proper heat treatment has been specified.

E. Does the design drawing give the necessary information for stamping the tool number on the completed tool or on loose parts that may be necessary for using the tool?

F. Has the tool number assigned to the drawing been duplicated?

G. Has the machine name and number been shown above the title block?

6. Indication of design revisions. In many manufacturing plants the same design of tool can be used for new piece parts with some revisions of the drawing. Therefore, the new drawing should be checked to show at what points changes have been made on the layout, and these should be indicated with a suitable letter and arrow. All revisions should be recorded on the assembly sheet and, if the drawing has additional sheets, the revisions that affect these additional sheets should be indicated on them.

QUIZ QUESTIONS

1. What are the two distinct groups of tools used in metal-manufacturing plants?
2. What are the qualifications of a good all-round tool designer?
3. Why is it important to keep tool designs as simple as possible?
4. In designing tools, what are some of the considerations that must be carefully weighed by the designer?
5. Why should the designer always use standard parts whenever they can be procured?
6. What are the five major factors that must be considered when designing a tool or fixture?
7. Discuss the term "tolerance" as used in machine manufacturing.
8. What is the value of the manual of procedure used in many drafting offices?
9. In checking drawings, what are the main points that the checker should consider?

MATERIALS

The tool designer at the present time may choose from a wide variety of materials. This is so because of constant technological and metallurgical developments during the past few years. The demands of the metalworking industry have been responsible for the introduction of these metals and alloys. While some of them are new, others have been known for some time but were not commercially available.

The automotive and aviation industries have been insistent in their demands for new materials which would solve some of their manufacturing problems. These new materials, coupled with improved methods, have had an effect on the design of tools. For example, the widespread use of tungsten carbide cutting tools has caused the machine tool manufacturers to change the designs on machine tools. These are made heavier and more rigid, and bearings have been increased in size to allow higher speeds and feeds. The tool designer also has had to keep pace with these developments and change his designs to provide for the use of tungsten carbides, etc.

On account of the low weight factor, the use of aluminum and its alloys is constantly increasing for jigs and fixtures. The aviation industry has been using magnesium and its alloys for some parts. This metal and its alloys require cutting tools of special design.

Fig. 1 illustrates an aluminum fixture for spot-welding the handle on an ordinary cooking utensil. Because of the lightness of aluminum jigs, the operator can handle them without much effort; this tends to decrease fatigue and increase production. The selection of proper materials for the design of tools, jigs, and fixtures is very important. Therefore, the tool designer should have an adequate working knowledge of the materials that are available. Considerable waste can be avoided and real economy can be effected in metalworking plants through the use of tools which are properly designed and constructed for each job, and which are made from the material best suited to the work being machined. In this way considerable money can be saved and real improvement made in the quality of the products.

A tool designer should consult manufacturers' catalogs for sizes and shapes of material before putting the size in the stock list on his drawing. Oftentimes by making slight changes in parts that cannot be made from stock items, a standard stock size can be used. Certain sizes of round, square, and rectangular shapes of steel are regularly stocked by the manufacturers. By designing the tools to incorporate these standard sizes, considerable time and money can be saved. For example, suppose a tool designer specifies that a bushing plate for a jig is to be made of ¾″ machine steel. This means that the plate will have to be machined top and bottom in order to obtain a true surface, as machine steel is hot-rolled. On the other hand, if cold-rolled steel is specified, this is rolled smooth so that the surface is suitable for the boring operations for the drill bushings without any machining of the top or bottom. The same is true in designing fixtures containing shafts. The designer should check the catalogs to see that the size of shaft he is going to use is standard. The following materials are those commonly specified by the tool designer in the average plant.

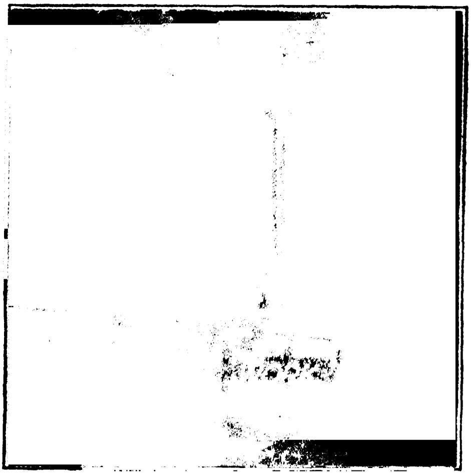


Fig. 1. Aluminum Fixture for Welding
Courtesy of Aluminum Co. of America, Pittsburgh, Pa.

Aluminum. Aluminum weighs approximately one-third as much as steel. Due to this lightness, it is being used for many jigs and fixtures that were formerly made of cast iron or steel plate. Aluminum handles are being put on tools, and parts of special machines are now being designed and made from this metal.

Brass. Brass is widely used in the average metalworking plant. This metal is an alloy of copper and zinc, usually about 60% is copper and 40% is zinc. Brass is a very ductile metal and is produced in various forms; for example, sheets, rods, squares, and rectangular shapes. It is extensively used in designing and making special machines, parts, etc.

Bronze. This metal has proved to be the most ideal bearing metal. Bronze is an alloy of copper, tin, lead, phosphor, and antimony; in some instances manganese is used to give it additional hardness. The use of bronze for bearings has decreased somewhat, particularly where the shafts revolve at a high rate of speed. This decrease has been caused by the introduction of ball, roller, and other types of antifriction bearings. However, bronze is used on a great number of machine tools for many of their bearings. On experimental jobs it is particularly valuable, as the cost is quite low in comparison with some of the other types of bearings.

Cast Iron. Cast iron is a metal frequently used by the tool designer in his designs of jigs, fixtures, certain types of cutting tools, special machines, and other equipment that is ordinarily made in the tool room. Iron is derived from iron ore, the largest percentage of which comes from the vicinity of Lake Superior, and is obtained from a very heavy reddish, stone-like material called hematite. This is an oxide of iron made up of 70% iron and 30% oxygen. Before this ore can be of any use it is put into a blast furnace. Charged with a mixture of iron ore, coke, and limestone, the furnace is lighted and the mixture results in a pig iron. The pigs contain about 92% iron and about 3½% to 4% carbon.

The pig iron is remelted in a cupola with certain other mixtures; the resulting product, when cast into useful shapes, is called *cast iron.* Cast iron, or gray iron as it is commonly called, contains approximately 2% to 2.5% carbon. During the past few years other alloys have been added to cast iron to form cast irons which are particularly adaptable for various phases of tool work; for instance, on a large forming die for automobile fenders, alloyed cast irons are extensively used. On certain types of drawing dies, other alloys have been found particularly suitable. Die sections can be cast to the form desired and a minimum amount of machining is necessary in order to produce the die required. The addition of nickel to cast iron has resulted in improvement of the machining qualities and in increased tensile strength. There has been considerable controversy over the relative merits of cast iron as compared to welded steel construction on jigs and fixtures, but the consensus of opinion still favors cast iron over other materials in designing tools, dies, jigs, and fixtures.

Malleable Iron. This metal is often used by the tool designer for certain parts of special machines, jigs, fixtures, and particularly for handwheels where considerable strength is required. Malleable iron is made from the white iron. This is the pig iron originally produced from iron ore. A certain percentage of scrap is added to the pig iron, which produces a hard white casting. It is so brittle that it cannot be used in its original state; therefore, to produce a malleable iron it is necessary to anneal these castings approximately 48 to 60 hours in a furnace at a temperature of approximately 1600°F. This produces a very strong casting.

Cold-Rolled Steel. This material is almost invaluable to the tool designer, as it comes in all shapes and sizes and, due to the rolling process, has a very smooth finish. Round cold-rolled steel shafts and rods are used for making pins and shafts for use in jigs and fixtures. The flat sections are used for the building of jigs, fixtures, dies, gages, etc. The tool designer finds almost innumerable uses for cold-rolled steel. It is stocked by most of the manufacturers of steel and is readily available at all times.

Drill Rod. Drill rod is a carbon tool steel which may be had in rounds or squares. It is cold drawn and in some instances is ground or polished to very accurate limits. Drill rod has a wide use in designing and building all types of tools. The tool designer specifies drill rod for various types of small cutters, pins of all types, and shafts, where it is necessary to have them hardened and ground. It is obtainable in all of the wire gage sizes up to and including 1 inch in diameter, and is usually 3 feet in length.

Hot-Rolled Steel. This is usually a low-carbon steel that is rolled to shape while hot. The surface produced is rough and it is necessary in many instances to specify that these surfaces be machined before using this material in various types of tools. Hot-rolled steels are also furnished in various shapes and sizes. One variation of hot-rolled steel is the so-called *tank plate* or *boiler plate*. This material is used for the construction of all types of jigs and fixtures, special machines, special die sets and other details that are ordinarily used in the fabricating of tools. The advent of the acetylene cutting torch has increased the use of tank plate in metal-working plants.

S.A.E. Steels. The series of analyses by the Society of Automotive Engineers has been generally recognized as the basis for the numerical representation and division ranges of the chemical analysis of steel in the United States. The S.A.E. steels are also called alloy steels. These standards were established a few years ago and most of the steel manufacturers adhere very closely to the S.A.E. gradings. Each of these steels has a numerical rating which is used by the tool designer on his drawings; for example, *S.A.E. 1020.* In carbon steels the S.A.E. numbers run from 1010 to 1095, and the last two numbers indicate approximately the carbon content. It is necessary for the tool designer to make a study of the various types of alloy steels that are available; each one has been produced for a definite purpose, to overcome some objection in other types of steel. The steel manufacturers usually provide catalogs giving the chemical and physical properties of these alloy steels, and the tool designer can save himself considerable time by consulting the manufacturer as to the proper steel for specific jobs. Most steel manufacturers are pleased to give the tool designer the necessary information.

Tool Steels. Tool steel has six principal classifications:

1. Carbon
2. Low-alloy
3. Nondeforming
4. Shock-resisting
5. Hot-work
6. High-speed

Carbon tool steels are divided into several different analyses, each one to suit the particular work for which it is intended. It would take considerable space to outline the different uses for which these carbon steels could be specified. Low-alloy steels are usually specified for parts of jigs, fixtures, dies, etc., where it is desired to carburize, harden, and then grind. Nondeforming steels are produced in various alloys to obtain the desired results. Some of the applications of these are: intricate blanking dies, ring gages, spline gages, master gears, master cams. These are oil-hardened steels and do not materially change shape or form in being heat treated. However, their abrasion-resisting qualities are not so good as some of the water-hardened steels.

Shock-resisting steels are used for making pneumatic chisels rivet sets, concrete drills, shear blades, and particularly for heavy materials and heavy-duty springs and spring collets. Hot-work tool steels are used in the designs of hot upsetter and bearing dies, hot bender dies, shear blades, and small drop-hammer dies. These steels retain their temper and hardness while working on material at high temperature.

High-speed tool steels are made in a number of analyses and in different alloys to give them specific qualities for certain definite purposes. Ordinary high-speed steel is called *18-4-1* and contains 65% to .75% carbon; however, this carbon content is seldom mentioned. This *18-4-1* high-speed steel has the following analysis:

Carbon	.65–.75%
Manganese	.20–.30%
Chromium	3.50–4.50%
Vanadium	.90–1.20%
Tungsten	17.50–19.00%

High-speed steel having this analysis remains a major tool material in spite of the various developments of tungsten carbide, Stellite, etc. It is widely used for the making of lathe and planer tools, form-cutting tools, reamers, drills, turning tools (particularly in a gang setup where it is not possible to run these tools at a maximum feed and speed), and for lathe centers. The addition of cobalt and molybdenum changes the quality of high-speed steel, but the tool designer should get expert advice from the steel manufacturer when called upon to produce certain types of tools from high-speed steel.

The tool designer employed in certain types of plants will be called upon to specify stainless steel, particularly where chemicals are being used; however, the use of stainless steel in designing tools is not common practice.

Tungsten Carbide. This new cutting metal has been developed during the past few years, being used particularly for machining iron, copper, brass, plastics, etc. The manufacture of this material has been closely controlled, and before attempting to specify different grades of tungsten carbide on the tools he has been called upon to design, the tool designer should obtain the advice of the manufacturer of this product. Designing tools of tungsten carbide offers innumerable problems, as there are numerous factors that must be taken into consideration. It is necessary to avoid extreme shocks in using this material for cutting tools. This metal is a product of the electric furnace; the tungsten itself is made into carbide and then cemented together by means of high heat in an electric furnace. It can cut various metals at much higher speeds than any other type of cutting material. Tools designed from tungsten carbide will be illustrated under *Cutting Tools.*

Stellite. This metal is largely used for cutting tools and for sections of other tools where great wear-resisting qualities must be assured. Stellite is a nonferrous metal containing various percentages of chromium and cobalt, with a small amount of molybdenum or tungsten. These latter two alloys make this metal particularly suited to the manufacture of high-speed lathe tools or cutters. This metal cannot be forged or machined except by grinding; it is cast to the size and shape desired. The outstanding advantage of Stellite is that cutting tools made from it retain their cutting quality even at red heat. Stellite cutting tools have proved to be remarkably efficient for machining gray iron castings; on certain types of low-carbon steels the results have not been so good. The use of Stellite has worked out very well in certain types of spotfacing cutters which are designed for machining surfaces of either rough gray iron or steel castings.

Nitriding Steels. This group of steels has been developed with an idea of obtaining steel of extremely hard surface and which is nondeforming. This steel is hardened in a furnace where ammonia is admitted to it to give it the surface hardening. When the ammonia enters the furnace it forms a gas, and the chemical reaction causes a very hard outer case on the work piece. Nitriding steels have been found particularly desirable for boring bars, as this extreme surface hardness provides excellent wearing qualities.

Other Metals. There are a number of additional materials that the tool designer will be called upon to work with on designs of various types of tools in *metalworking plants. Some of these are not fully developed at the present time, and new alloys and various* types of metals are being constantly developed to suit the particular needs of various industries. It is therefore essential that the tool designer try to keep abreast of the development of these materials.

ALLOWANCE OF STOCK FOR BENDS

In stamping or forming sheet metal, it is necessary to develop blanks for forming. Particularly where 90° bends are made, it is desirable for the tool designer to know just how much stock he must allow. The table, Fig. 2, shows the amount of allowance to be made for these 90° bends. The amount of the radius allowed has been calculated so as to determine the exact length of the flat blank. A table of this kind saves the tool designer considerable time and is an improvement over the old cut-and-try method.

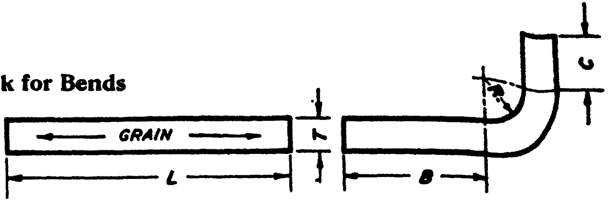
HARDNESS OF METALS

The tool designer is called upon to determine the degree of hardness for various types of cutting tools, also the hardness of various drills, jigs, fixtures, dies, gages, etc. He is also confronted many times with drawings on which he must indicate heat treatment to various degrees of hardness.

There are several different means of determining the hardness of articles made from metal; among them is the Rockwell hardness tester. This instrument has a diamond point which penetrates the surface of the metal and gives a reading in numbers as to the hardness of the part being checked. The Brinell system is somewhat similar except that it has a hardened steel ball which is pressed into the material under a known load. The diameter of the impression made in the part is read through a measuring microscope, and the hardness is determined by dividing the known load by the diameter of the impression. Other systems are the Vickers or Firth diamond hardness number, and the Scleroscope. The hardness of the part is determined by this last instrument by means of a steel ball. The rebound of this steel ball on the work indicates the approximate hardness.

These various systems are used by different plants, and it is

Allowance of Stock for Bends



ALLOWANCE = $\left(\frac{T}{3} + R\right) \times 1.5708''$

This table is for 90-degree bends made in V-type dies and formed across the grain. To find length of flat blank, add to dimensions of straight sections, allowance *Y* at bend, for given radius and stock thickness *T*.

Example: Find length *L* of flat blank (see illustration) if *C* = ½ inch, *B* = ¾ inch, *R* = 3/16 inch, and *T* = 1/16. Allowance *Y* in table = 0.3272 (See opposite 1/16 and under 3/16); hence *L* = ½ plus ¾ plus 0.3272 = 1.5772 inches.

Thickness (T) of Stock Inch	Inside Radius (R) of Bends, Inch										
	0	1/64	1/32	1/16	3/32	1/8	5/32	3/16	7/32	1/4	9/32
	Allowance (Y) for Bends										
.0102	.0053	.0299	.0544	.1035	.1526	.2017	.2508	.2999	.3489	.3980	.4471
.0141	.0074	.0319	.0565	.1055	.1546	.2037	.2528	.3002	.3510	.4001	.4492
.0188	.0098	.0344	.0589	.1080	.1571	.2062	.2553	.3044	.3535	.4025	.4516
.0250	.0131	.0376	.0622	.1113	.1603	.2094	.2585	.3076	.3567	.4058	.4549
1/32	.0164	.0409	.0654	.1145	.1636	.2127	.2618	.3109	.3600	.4091	.4581
.0344	.0180	.0425	.0671	.1162	.1653	.2144	.2634	.3125	.3616	.4117	.4598
.0500	.0262	.0507	.0753	.1243	.1734	.2225	.2716	.3207	.3698	.4189	.4680
1/16	.0327	.0573	.0818	.1309	.1800	.2291	.2782	.3272	.3763	.4254	.4745
.0650	.0340	.0586	.0831	.1322	.1813	.2304	.2795	.3286	.3776	.4267	.4758
.0703	.0368	.0613	.0859	.1350	.1841	.2331	.2822	.3313	.3804	.4295	.4786
5/64	.0409	.0654	.0900	.1391	.1882	.2372	.2863	.3354	.3845	.4336	.4827
.0830	.0434	.0680	.0925	.1416	.1907	.2398	.2889	.3380	.3871	.4362	.4852
3/32	.0491	.0736	.0982	.1473	.1964	.2454	.2945	.3436	.3927	.4418	.4909
.0950	.0497	.0743	.0988	.1479	.1970	.2461	.2952	.3443	.3934	.4424	.4915
7/64	.0572	.0818	.1063	.1554	.2045	.2536	.3027	.3518	.4009	.4500	.4990
1/8	.0654	.0900	.1145	.1636	.2127	.2618	.3109	.3600	.4091	.4581	.5072
5/32	.0818	.1064	.1309	.1800	.2291	.2782	.3273	.3763	.4254	.4745	.5212
3/16	.0982	.1227	.1473	.1964	.2454	.2945	.3436	.3927	.4418	.4909	.5400

Fig. 2

Hardness Conversion Table

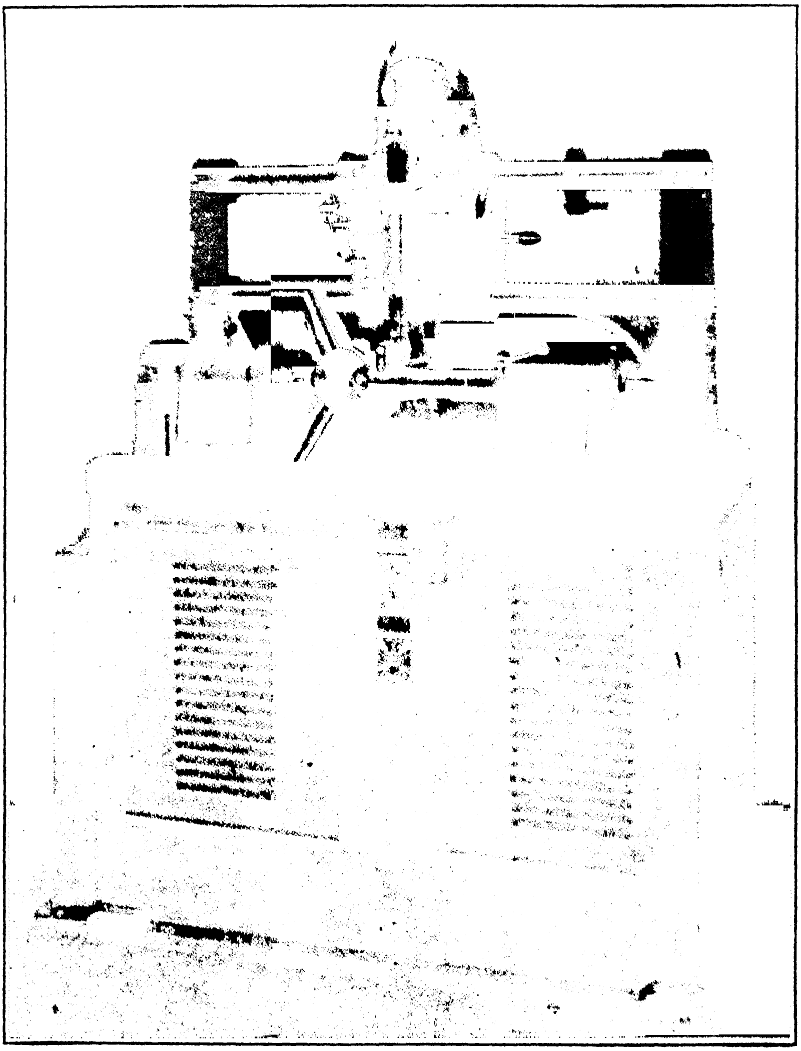
Rockwell				Brinell		Equivalent	Vickers or Firth	Scleroscope
B Scale	Diamond C Scale			10 Mm Ball, 3000 Kgm Load				
1/16 Ball 100 Kgm	150 Kgm.	100 Kgm	60 Kgm	Diam of Impression in Mm	Hardness Number	1000 Lb Sq. In.	Diamond Hardness Number	Number
				2 00	946	464		
				2 05	898	439		
				2 10	857	419		
				2 15	817	399		
	72	82	89	2 20	782	383	1220	107
	69	80	87	2 25	744	365	1114	100
	67	78	85	2 30	713	350	1021	96
	65	76	84	2 35	683	334	940	92
	63	74	83	2 40	652	318	867	88
	61	72	82	2 45	627	307	803	85
	59	71	81	2 50	600	294	746	81
	58	69	80	2 55	578	282	694	78
	56	68	79	2 60	555	271	649	75
	54	67	78	2 65	532	260	606	72
	52	65	77	2 70	512	251	587	70
	51	64	76	2 75	495	242	551	68
	49	63	76	2 80	477	233	534	66
	48	62	75	2 85	460	226	502	64
	47	61	74	2 90	444	217	474	61
	45	60	73	2 95	430	210	460	59
	44	59	73	3 00	418	205	435	57
	43	58	72	3 05	402	197	423	55
	41	57	71	3 10	387	189	401	53
	40	56	71	3 15	375	183	390	52
	39	55	70	3 20	364	178	380	50
	38	54	69	3 25	351	172	361	49
	37	53	69	3 30	340	167	344	47
	36	52	68	3 35	332	162	335	46
	35	52	68	3 40	321	157	320	45
	34	51	67	3 45	311	152	312	44
	33	50	67	3 50	302	148	305	42
	31	49	66	3 55	293	144	291	41
	30	49	66	3 60	286	140	285	40
	29	48	65	3 65	277	136	278	39
	28	47	65	3 70	269	132	272	38
	27	46	64	3 75	262	128	261	37
	26	45	64	3 80	255	125	255	36
	25	45	63	3 85	248	121	250	36
100	24	44	63	3 90	241	118	240	35
99	23	43	62	3 95	235	115	235	34
98	22	42	62	4 00	228	113	226	33
97	21	41	61	4 05	223	109	221	33
97	20	41	61	4 10	217	106	217	32
96	19	40	60	4 15	212	104	213	31
95	18	39	60	4 20	207	101	209	30
94		38	59	4 25	202	99	201	30
93		37	58	4 30	196	96	197	29
92		36	58	4 35	192	94	190	29
91		35	57	4 40	187	91	186	28
89		34	56	4 45	183	90	183	28
88		34	56	4 50	179	89	177	27
87		33	55	4 55	174	88	174	27
86		32	55	4 60	170	86	171	26
85			54	4 65	166	85	165	26
84			53	4 70	163	84	162	25
83			53	4 75	159	82	159	25
82			52	4 80	156	80	154	24
81			52	4 85	153	79	152	24
80			51	4 90	149	77	149	23
78			50	4 95	146	75	147	23
76			50	5 00	143	73	144	22
76				5 05	140	72		
75				5 10	137	70		
74				5 15	134	69		
72				5 20	131	68		
71				5 25	128	66		
69				5 30	126	65		
69				5 35	124	63		
67				5 40	121	62		
66				5 45	118	61		

Fig 3

necessary to have a conversion table to determine just what the hardness would be if measured by some other system than the one used in the plant where the tool designer works. Therefore Fig. 3 is a table showing the comparison of the various systems. For the Rockwell system the *C* scale is generally used, and the tool designer will notice on some drawings the following note: *Material S.A.E. 3140 heat treated to 29-31 Rockwell C.* This specifies that the *C* scale on the Rockwell system is used.

QUIZ QUESTIONS

1. In what ways has the introduction of many new materials affected the design of tools?
2. Why is it important for the tool designer to consult manufacturers' catalogs regarding sizes and shapes of materials before inserting sizes in the stock list on his drawings?
3. Why is aluminum used in many jigs and fixtures?
4. What are some of the important uses of bronze in machine manufacturing?
5. In what types of jobs does the tool designer use cast iron?
6. What makes cold-rolled steel an invaluable material to the tool designer?
7. What are some of the uses that a tool designer makes of drill rod?
8. What are the six principal classifications of tool steels?
9. What is the analysis of *18-4-1* high-speed steel?
10. Name some of the uses of high-speed steel in tool making.
11. When using tungsten carbide as a cutting tool, what precautions must the tool designer use?
12. What important use does the tool designer make of Stellite?
13. What are some of the peculiar qualities of nitriding steel?
14. Name the several methods for determining the hardness of metals.

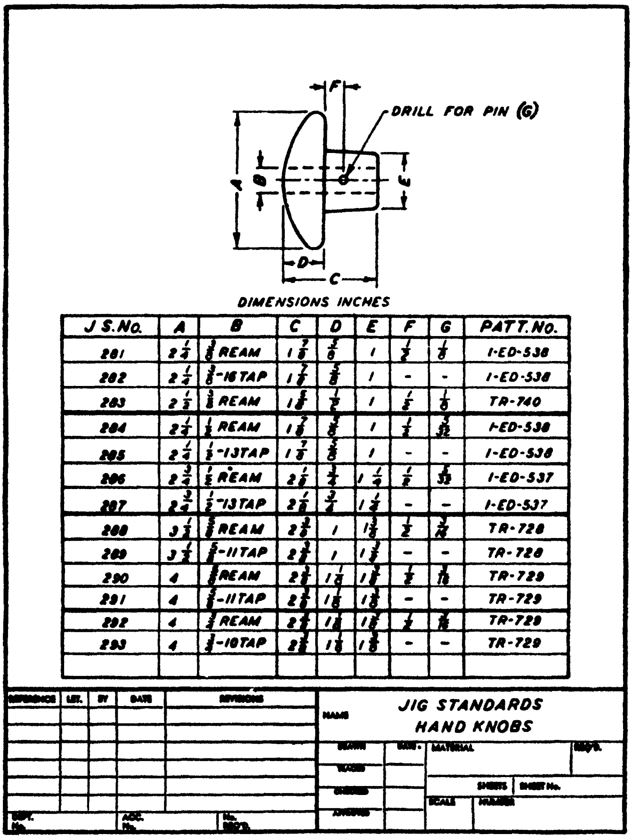


A SUPERFINISHING MACHINE FOR AIRCRAFT PROPELLER HUBS

Courtesy of Foster Machine Co Elkhart Ind

JIG AND FIXTURE AND TOOL DESIGN STANDARDS

In many of the metal-manufacturing plants of this country, during a period of years, certain definite standards of tool designing have been adopted. This has come about in some instances by the painful and tedious process of trial and error. In other plants, wasteful duplication of tool designs has caused the setting up of these various standards.



DIMENSIONS INCHES

J S. No.	A	B	C	D	E	F	G	PATT. No.
281	2 1/4	3/8 REAM	1 7/8	5/8	1	1/2	1/8	1-ED-538
282	2 1/4	3/8-16 TAP	1 7/8	5/8	1	-	-	1-ED-538
283	2 1/2	3/8 REAM	1 5/8	1/2	1	1/8	1/8	TR-740
284	2 1/4	1/2 REAM	1 7/8	5/8	1	1/2	5/32	1-ED-538
285	2 1/4	1/2-13 TAP	1 7/8	5/8	1	-	-	1-ED-538
286	2 3/4	1/2 REAM	2 1/8	3/4	1 1/4	1/2	5/32	1-ED-537
287	2 3/4	1/2-13 TAP	2 1/8	3/4	1 1/4	-	-	1-ED-537
288	3 1/2	5/8 REAM	2 3/8	1	1 3/8	1/2	3/16	TR-728
289	3 1/2	5/8-11 TAP	2 3/8	1	1 3/8	-	-	TR-728
290	4	5/8 REAM	2 3/8	1 1/8	1 3/8	1/2	3/16	TR-729
291	4	5/8-11 TAP	2 3/8	1 1/8	1 3/8	-	-	TR-729
292	4	3/4 REAM	2 3/8	1 1/8	1 3/8	1/2	3/16	TR-729
293	4	3/4-10 TAP	2 3/8	1 1/8	1 3/8	-	-	TR-729

JIG STANDARDS
HAND KNOBS

Fig. 1

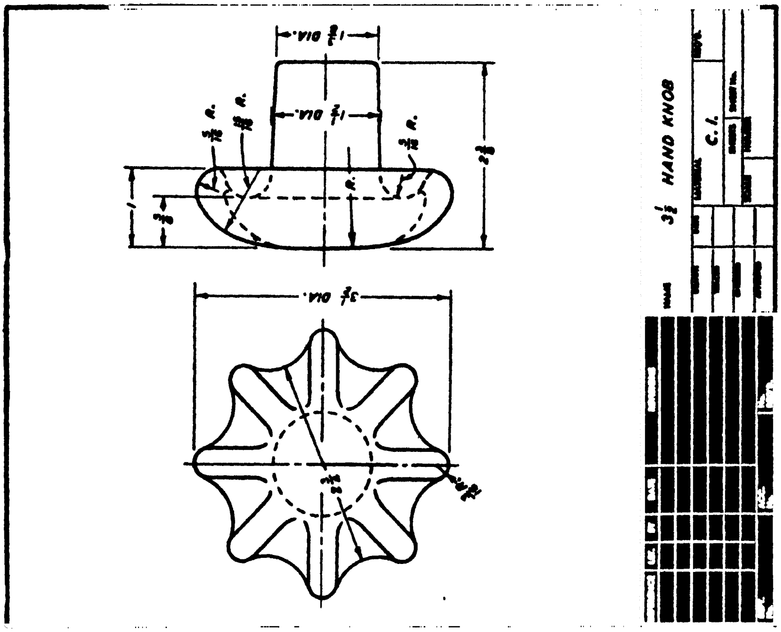

1 3/8 DIA.
1 1/4 DIA.
5/16 R.
11/16 R.
3/16 R.
R.
2 1/8
1
3/8
3 1/2 DIA.
3 1/2 HAND KNOB
C.I.

Fig. 3

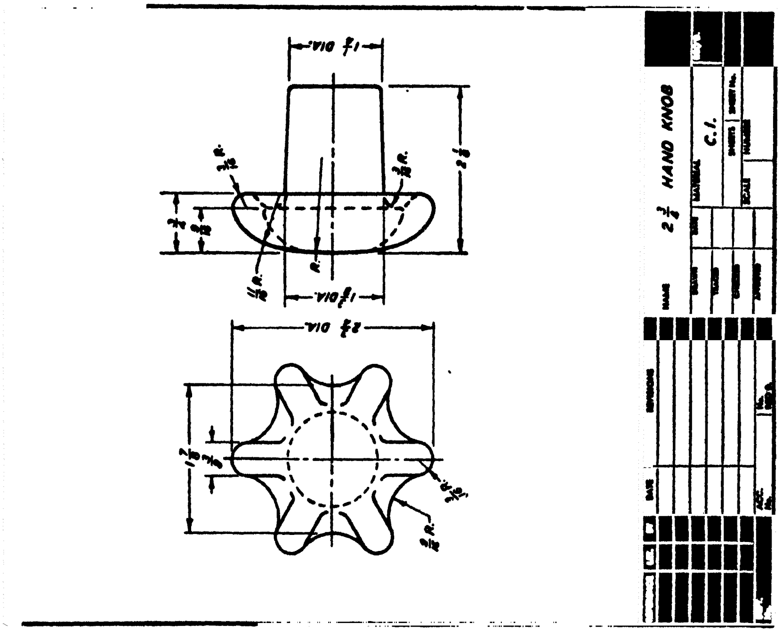

1 1/4 DIA.
3/16 R.
3/16 R.
2 1/8
3/4
3/16
11/16 R.
R.
1 1/4 DIA.
2 3/4 DIA.
1 7/16
3/8
3/16 R.
3/8 R.
2 3/4 HAND KNOB
C.I.

Fig. 2

Their adoption has not been complete throughout the industrial centers of this country, but there is a tendency toward standardization of tool designing methods and standards. Due to the rapid changes in the variety of products manufactured, it is very difficult to set definite standards in some plants, while in other plants the product remains the same except for minor changes. Therefore, the standards that are to follow are to be taken as suggestions as to what might be adopted in some plants. Certain items are common to the majority of plants engaged in the manufacture of articles made of metals.

Hand Knobs. The hand knob shown in Fig. 1 is in common use on a great many types of jigs and fixtures. In many tool designing departments and manufacturing plants, standard forms of hand knobs are adopted, and, in the event of placing work on the outside with local tool shops, these plants generally advise the tool shops that they will furnish these knobs. By having a pattern and a quantity of these castings on hand, considerable time is saved in fabricating the tools. It is only necessary to drill a hole through the hub (*B* of Fig. 1) for the insertion of the screw, and a pin hole (*G* of Fig. 1) is drilled at right angles in order to fasten the handle to the screw. It will be noted that a chart is shown which gives sizes of hand knobs from 2¼" diameter up to 4" diameter.

The knob shown in Fig. 1 is smooth. This is used for jobs where not much pressure is required to lock the part in the jig or fixture. Another standard form of hand knob is the one shown in Fig. 2. This type is used on jigs and fixtures where a cutting com pound is used and where the operator's hand might be slippery. These indentations furnish a good grip on the hand knob.

Fig. 3 is a larger size used for jigs and fixtures where considerable pressure might be required. Fig. 4 is a still larger hand knob permitting the operator to get a firmer grip.

In conjunction with hand knobs, standards have been worked out on the knob screws, Fig. 5. These generally are arranged so that they can be made in quantities and are available for immediate use in the toolroom. This saves designing time and also considerable time in the shop in fabricating the tools. Note that there is a chart showing all dimensions and these screws are arranged so they can take care of the various sizes of hand knobs regularly used.

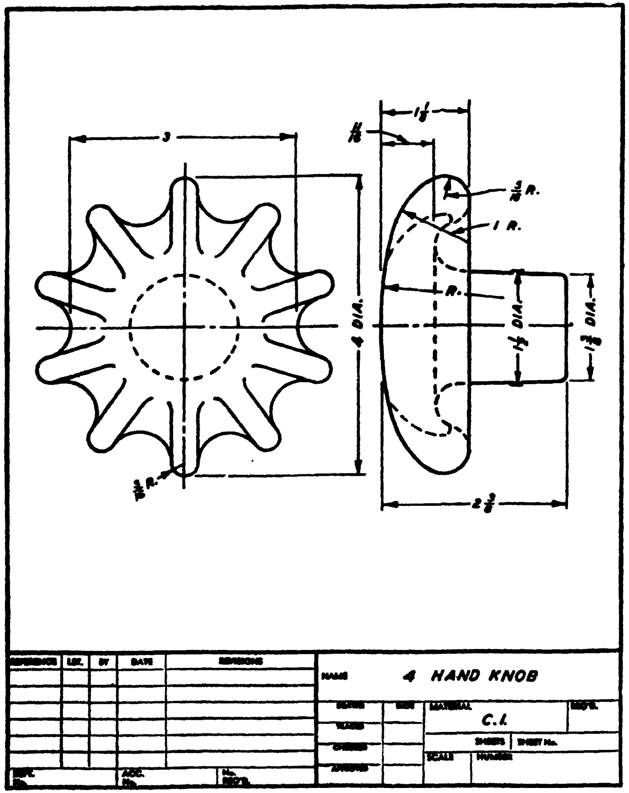
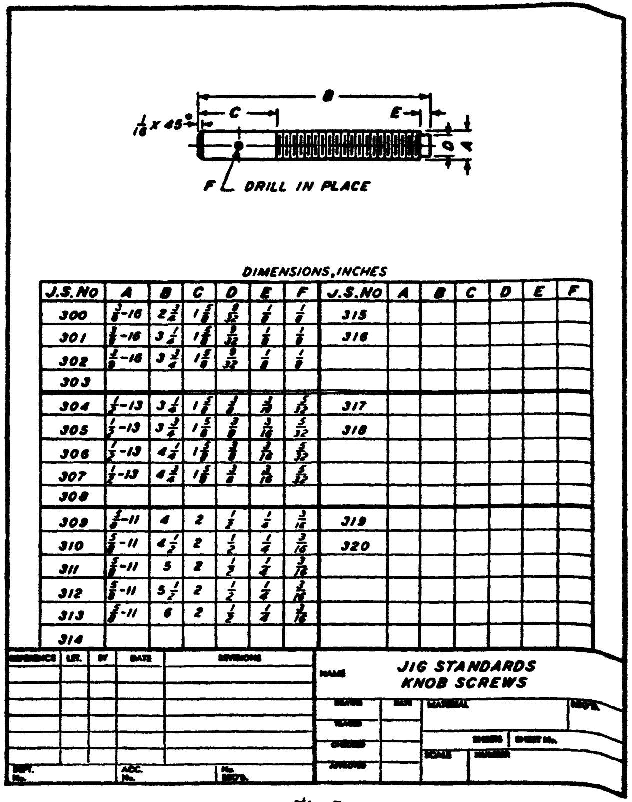


Fig. 4



DIMENSIONS, INCHES

J.S.NO	A	B	C	D	E	F	J.S.NO	A	B	C	D	E	F
300	3/8-16	2 3/4	1 5/8	9/32	1/8	1/8	315						
301	3/8-16	3 1/4	1 5/8	9/32	1/8	1/8	316						
302	3/8-16	3 3/4	1 5/8	9/32	1/8	1/8							
303													
304	1/2-13	3 1/4	1 5/8	3/8	3/16	5/32	317						
305	1/2-13	3 3/4	1 5/8	3/8	3/16	5/32	318						
306	1/2-13	4 1/4	1 5/8	3/8	3/16	5/32							
307	1/2-13	4 3/4	1 5/8	3/8	3/16	5/32							
308													
309	5/8-11	4	2	1/2	1/4	3/16	319						
310	5/8-11	4 1/2	2	1/2	1/4	3/16	320						
311	5/8-11	5	2	1/2	1/4	3/16							
312	5/8-11	5 1/2	2	1/2	1/4	3/16							
313	5/8-11	6	2	1/2	1/4	3/16							
314													

Fig. 5

Handwheels. *In Fig. 6 is shown a handwheel. These are used* extensively on jigs, fixtures, special machines, etc. A standard has been worked out on these handwheels, and patterns are maintained in the shop so that castings can readily be obtained and machined for use when required for installations on jigs, fixtures, etc. The chart gives the various diameters and other necessary dimensions.

DIMENSIONS INCHES

No.	No. OF SPOKES	A	B	C	D	E	F	G	H	J	K	L	M	N	P	Q	WT. LBS.
1	SOLID	4	1.32	1.00	1.5	.76	.38	.32	$\frac{5}{32}$	$\frac{3}{8}$-16	$\frac{3}{8}$	.16	.500	.12	.62	—	2.0
2	4	6	2.24	1.24	1.88	1.0	.44	.38				.32	.625	.16		.62	3.12
3		8	3.00	1.38	2.12	1.12	.5	.44	$\frac{3}{16}$	$\frac{1}{2}$-13	$\frac{1}{2}$		.750	.18	1.00	.88	6.88
4	5	10	3.94	1.62	2.38	1.26	.56	.5	$\frac{7}{32}$			.44	.875	.22		.82	11
5		12	4.88	1.88	2.76	1.5	.62	.56	$\frac{1}{4}$			.5	1.000	.26		.94	16.62
6		15	6.38														17.26
7	6	20	8.88	2.60	3.5	2.0	.76	.7	$\frac{5}{16}$				1.250	.32		1.0	35
8		26	11.50	3.26	4.26	2.4	.88	.82	$\frac{3}{8}$			.62		.38	1.12	1.26	43

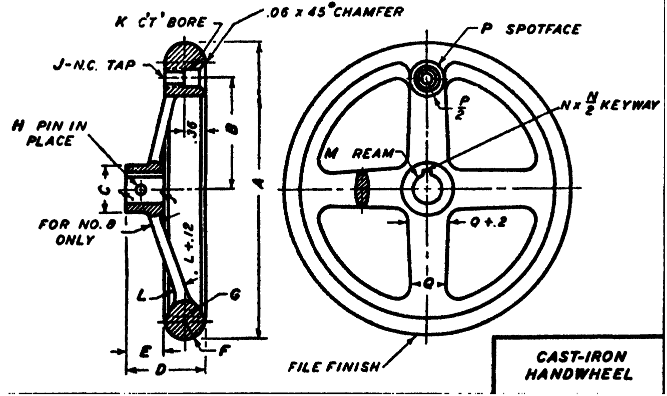
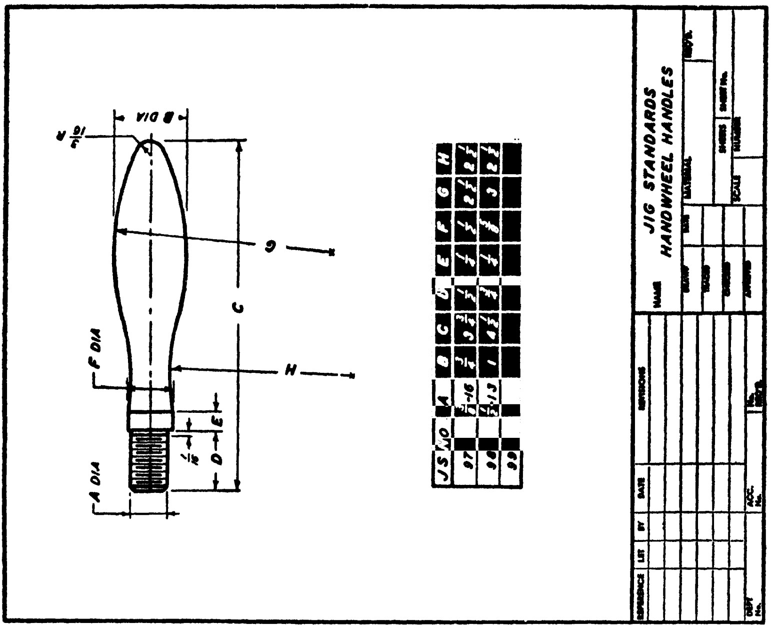


Fig. 6

By having a standard of this kind, considerable time is saved in designing, due to the fact that in the list of specifications the number of the handwheel is mentioned and this eliminates the necessity of drawing out the handwheel in detail and dimensioning it.

Fig. 7 illustrates another type of handwheel. This one is designed for one size only. Variations of this could be made and a chart laid out to show the range of sizes used in the average plant.

Handwheel Handles. Each handwheel should have a handle attached to it to facilitate operation. Fig. 8 illustrates a standard handle and this can be made up in various sizes to suit requirements.



JS NO	A	B	C	D	E	F	G	H
97	5/16-16	3/4	3 3/4	1/2	1/4	1/2	2 1/2	2 1/2
98	1/2-13	1	4 1/2	3/4	1/4	5/8	3	2 1/2
99								

Fig. 8

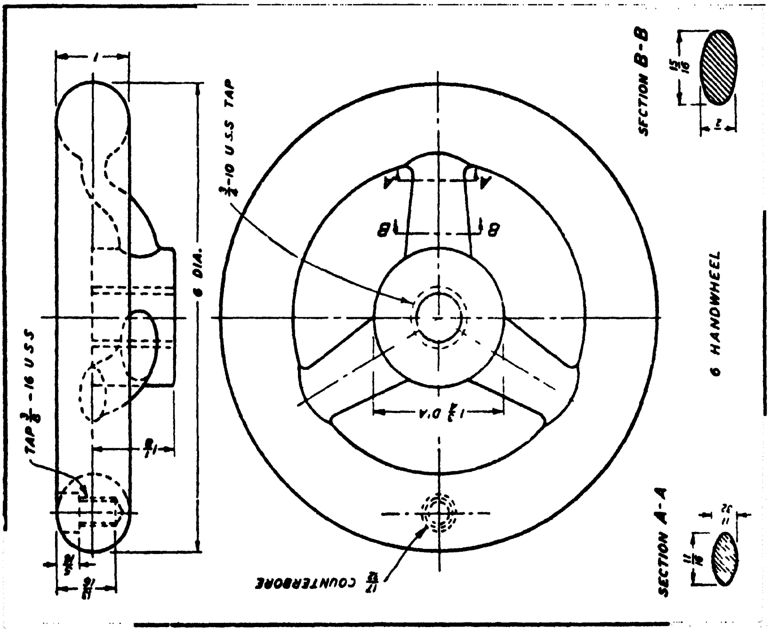


Fig. 7

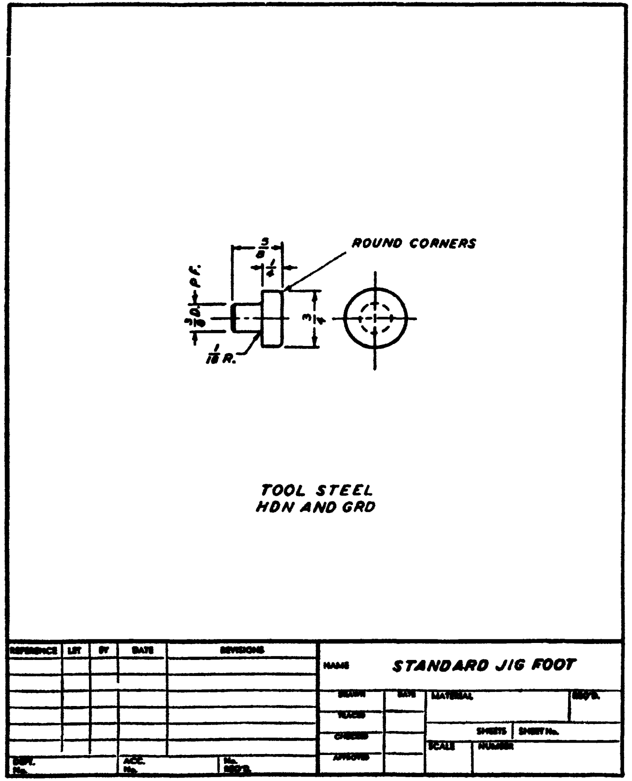
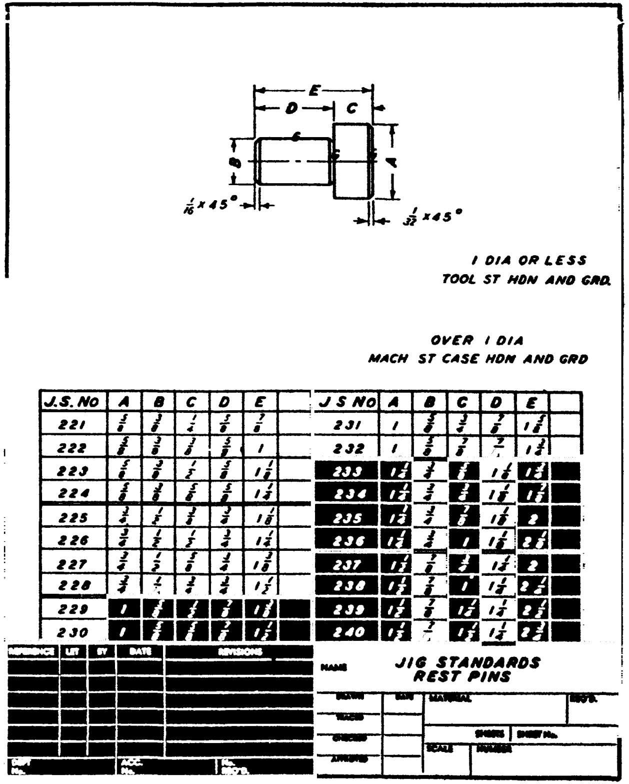


Fig. 9



J.S. No	A	B	C	D	E	
221	$\frac{5}{8}$	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{5}{8}$	$\frac{7}{8}$	
222	$\frac{5}{8}$	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{5}{8}$	1	
223	$\frac{5}{8}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$1\frac{1}{8}$	
224	$\frac{5}{8}$	$\frac{3}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	$1\frac{1}{4}$	
225	$\frac{3}{4}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{3}{4}$	$1\frac{1}{8}$	
226	$\frac{3}{4}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{3}{4}$	$1\frac{1}{4}$	
227	$\frac{3}{4}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$1\frac{3}{8}$	
228	$\frac{3}{4}$	$\frac{1}{2}$	$\frac{3}{4}$	$\frac{3}{4}$	$1\frac{1}{2}$	
229	1	$\frac{5}{8}$	$\frac{1}{2}$	$\frac{7}{8}$	$1\frac{3}{8}$	
230	1	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{7}{8}$	$1\frac{1}{2}$	

J S No	A	B	C	D	E	
231	1	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	$1\frac{5}{8}$	
232	1	$\frac{5}{8}$	$\frac{7}{8}$	$\frac{7}{8}$	$1\frac{3}{4}$	
233	$1\frac{1}{4}$	$\frac{3}{4}$	$\frac{5}{8}$	$1\frac{1}{8}$	$1\frac{3}{4}$	
234	$1\frac{1}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$1\frac{1}{8}$	$1\frac{7}{8}$	
235	$1\frac{1}{4}$	$\frac{3}{4}$	$\frac{7}{8}$	$1\frac{1}{8}$	2	
236	$1\frac{1}{4}$	$\frac{3}{4}$	1	$1\frac{1}{8}$	$2\frac{1}{8}$	
237	$1\frac{1}{2}$	$\frac{7}{8}$	$\frac{3}{4}$	$1\frac{1}{4}$	2	
238	$1\frac{1}{2}$	$\frac{7}{8}$	1	$1\frac{1}{4}$	$2\frac{1}{4}$	
239	$1\frac{1}{2}$	$\frac{7}{8}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$2\frac{1}{2}$	
240	$1\frac{1}{2}$	$\frac{7}{8}$	$1\frac{1}{2}$	$1\frac{1}{4}$	$2\frac{3}{4}$	

Fig. 10

Jig Feet. *When designing small jigs (either the leaf or box type) made out of cast iron, it is usually good practice to insert* hardened and ground jig feet. These will prevent wearing of the body of the jig and preserve its accuracy over a long period. Fig. 9 illustrates the type of jig foot that is in common use. This is made out of tool steel and hardened to resist wear. Various sizes can be established, depending on the needs of the individual plant.

Rest Pins. These are used extensively in designing jigs and fixtures. They are usually put in jigs where the surface is not machined. It is only necessary to drill and spotface to obtain a true surface and then insert a rest pin. These can either be ground after insertion, or the surface may be machined to a definite limit before the insertion of the rest pin. Fig. 10 illustrates a standard rest pin with a chart accompanying the design to show the variations in sizes.

Rest Pads. On some types of jigs and fixtures it is preferable to use a rest pad instead of a pin. Fig. 11 illustrates a type of rest pad that is readily adapted to a wide variety of jobs. This is made out of a low-carbon steel and is pack-hardened and ground. Various sizes of these can be standardized so as to fit the requirements of most of the jobs in the plant.

Locator Pins. In designing jigs and fixtures for parts that must be located in definite relation to mating parts (such as covers for speed-reducer housings, top and bottom halves of centrifugal pump housings, etc.) it is necessary to use locator pins. These pins are placed in the jig or fixture so that they will hold the casting in the proper position in the fixture for subsequent machining operations. Fig. 12 illustrates the type of locator pin in general use, with an accompanying chart to show the variations in sizes.

In conjunction with round locator pins a relieved form of locator pin, Fig. 13, is also used. The reason for the relief on this type of pin is due to the fact that it permits the part to have some play in the jig or fixture without interfering with alignment. This type of pin also permits ready removal of the part from the jig or fixture. A chart accompanies this to show the variations in sizes.

Fig. 14 illustrates a design of round locator pin with all dimensions detailed. Fig. 15 illustrates a flatted or relieved locating pin and shows drawings with dimensions for each size. This could be used to establish a standards table such as shown in Fig. 13.

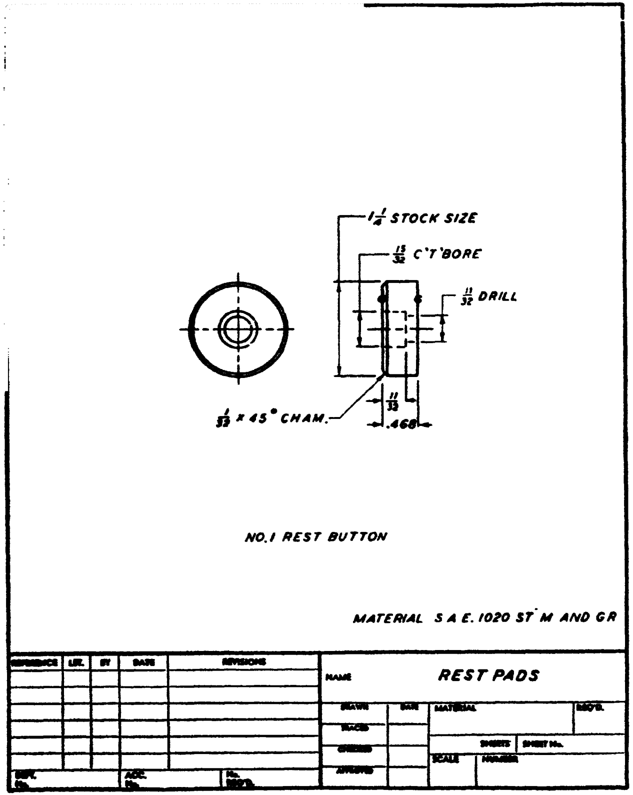
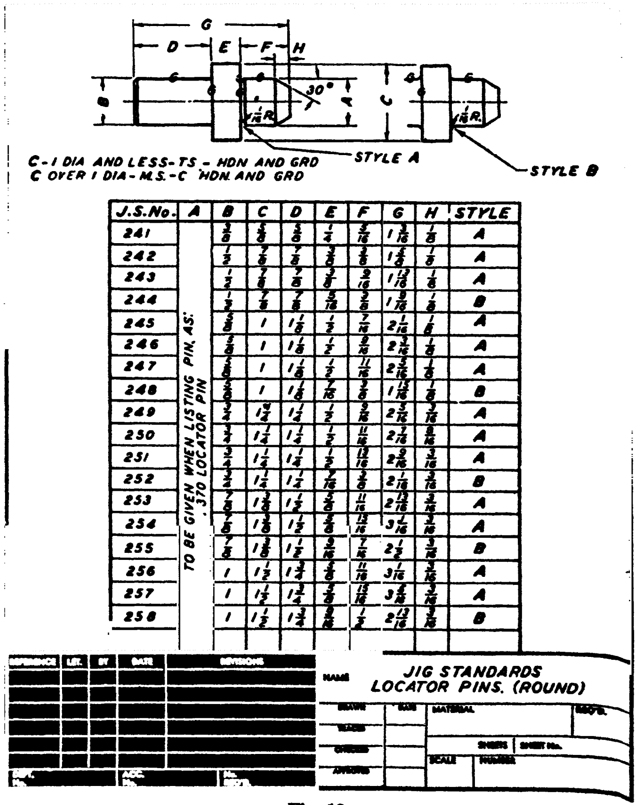
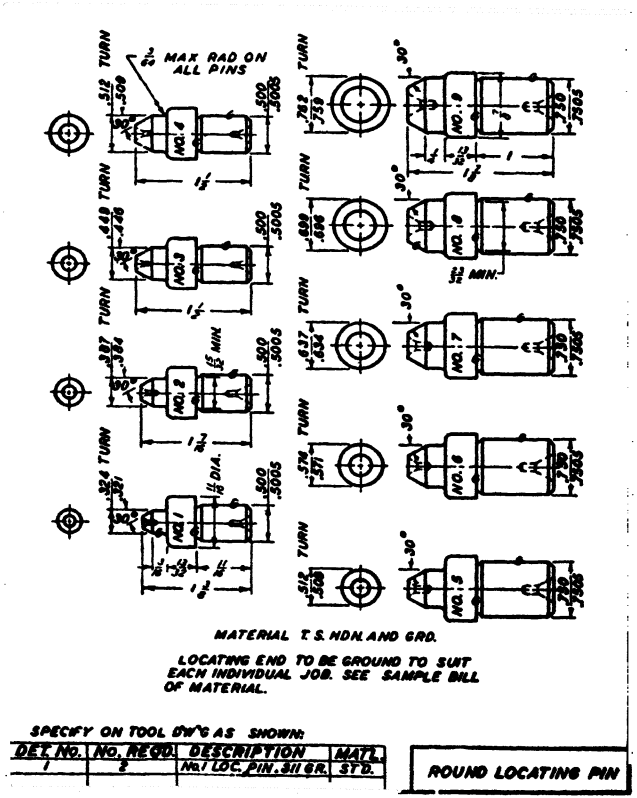


Fig. 11



J.S.No.	A	B	C	D	E	F	G	H	STYLE
241	TO BE GIVEN WHEN LISTING PIN, AS: .370 LOCATOR PIN	3/8	5/8	5/8	1/4	3/16	1 3/16	1/8	A
242		1/2	7/8	7/8	3/8	3/8	1 5/8	1/8	A
243		1/2	7/8	7/8	3/8	9/16	1 13/16	1/8	A
244		1/2	7/8	7/8	5/16	3/8	1 9/16	1/8	B
245		5/8	1	1 1/8	1/2	7/16	2 1/16	1/8	A
246		5/8	1	1 1/8	1/2	9/16	2 3/16	1/8	A
247		5/8	1	1 1/8	1/2	11/16	2 5/16	1/8	A
248		5/8	1	1 1/8	7/16	3/8	1 13/16	1/8	B
249		3/4	1 1/4	1 1/4	1/2	9/16	2 5/16	3/16	A
250		3/4	1 1/4	1 1/4	1/2	11/16	2 7/16	3/16	A
251		3/4	1 1/4	1 1/4	1/2	13/16	2 9/16	3/16	A
252		3/4	1 1/4	1 1/4	7/16	3/8	2 1/16	3/16	B
253		7/8	1 3/8	1 1/2	5/8	11/16	2 13/16	3/16	A
254		7/8	1 3/8	1 1/2	5/8	13/16	3 1/16	3/16	A
255		7/8	1 3/8	1 1/2	9/16	7/16	2 1/2	3/16	B
256		1	1 1/2	1 3/4	5/8	11/16	3 1/16	3/16	A
257		1	1 1/2	1 3/4	5/8	15/16	3 5/16	3/16	A
258		1	1 1/2	1 3/4	9/16	1/2	2 13/16	3/16	B

Fig. 12



MATERIAL T. S. HDN. AND GRD.

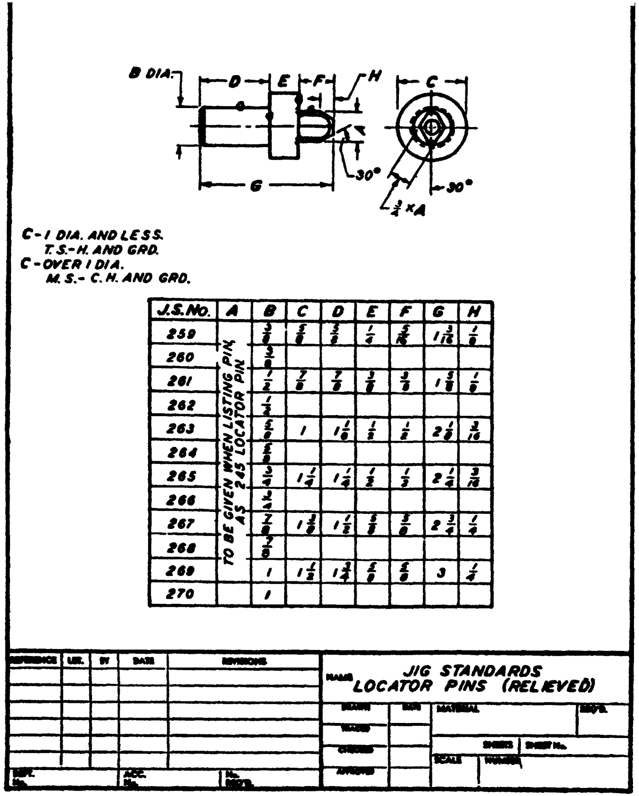
LOCATING END TO BE GROUND TO SUIT EACH INDIVIDUAL JOB. SEE SAMPLE BILL OF MATERIAL.

SPECIFY ON TOOL DW'G AS SHOWN:

DET. NO.	NO. REQ'D.	DESCRIPTION	MAT'L.
1	2	No. 1 LOC. PIN. 311 GR.	STD.

ROUND LOCATING PIN

Fig. 14



C-1 DIA. AND LESS.
T. S.-H. AND GRD.
C-OVER 1 DIA.
M. S.- C. H. AND GRD.

J.S. No.	A	B	C	D	E	F	G	H
259	TO BE GIVEN WHEN LISTING PIN AS 245 LOCATOR PIN	3/8	5/8	5/8	1/4	5/16	1 3/16	1/8
260		3/8						
261		1/2	7/8	7/8	3/8	3/8	1 5/8	1/8
262		1/2						
263		5/8	1	1 1/8	1/2	1/2	2 1/8	3/16
264		5/8						
265		3/4	1 1/4	1 1/4	1/2	1/2	2 1/4	3/16
266		3/4						
267		7/8	1 3/8	1 1/2	5/8	5/8	2 3/4	1/4
268		7/8						
269		1	1 1/2	1 3/4	5/8	5/8	3	1/4
270		1						

JIG STANDARDS
NAME LOCATOR PINS (RELIEVED)

Fig. 13

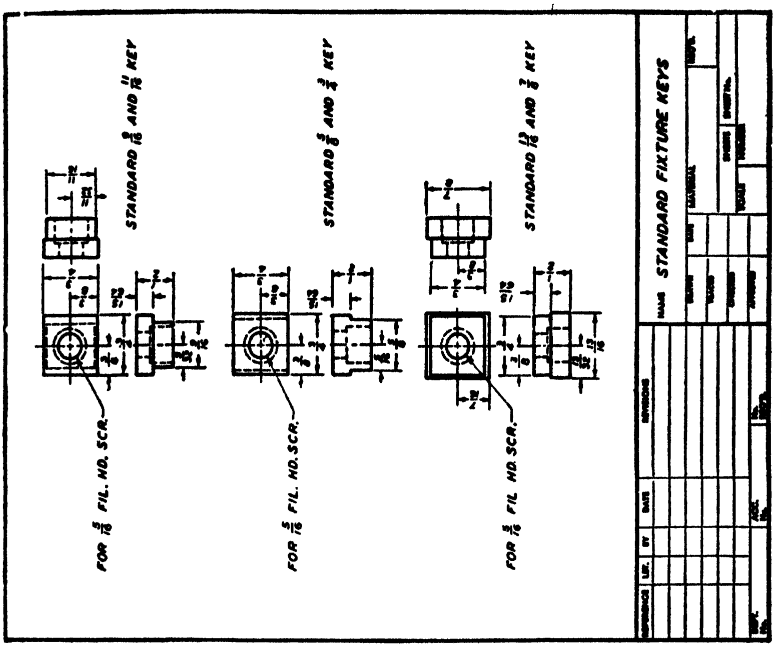

STANDARD 9/16 AND 11/16 KEY
FOR 5/16 FIL. HD. SCR.
STANDARD 5/8 AND 3/4 KEY
FOR 5/16 FIL. HD. SCR.
STANDARD 13/16 AND 7/8 KEY
FOR 5/16 FIL HD. SCR.
STANDARD FIXTURE KEYS

Fig. 16

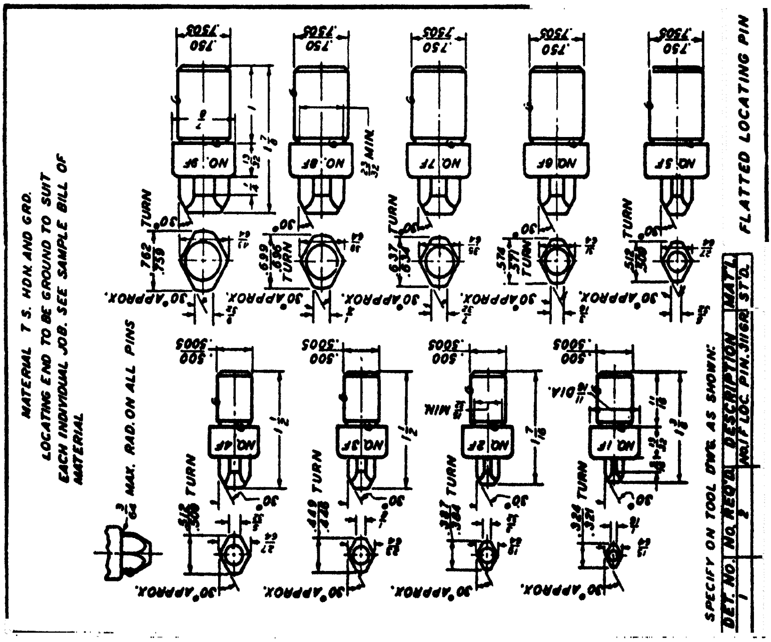

MATERIAL T.S. HDN. AND GRD.
LOCATING END TO BE GROUND TO SUIT EACH INDIVIDUAL JOB. SEE SAMPLE BILL OF MATERIAL
3/64 MAX. RAD. ON ALL PINS
NO. 1F
NO. 2F
NO. 3F
NO. 4F
NO. 5F
NO. 6F
NO. 7F
NO. 8F
NO. 9F
TURN
30° APPROX.
.500
.5005
.750
.7505
FLATTED LOCATING PIN
SPECIFY ON TOOL DWG. AS SHOWN:
DET. NO.
NO. REQ'D
DESCRIPTION
MAT'L
1
2
NO. 1F LOC. PIN. 311GR
ST'D.

Fig. 15

Keys. All milling fixtures must have keys attached to the bottom of the fixture to fit in the **T** slots of the milling machine table. This permits the definite location of the fixture on the milling machine table in relation to the arbor and the cutters. Fig. 16 shows standards that have been worked out to take care of three different sizes. This form of key is in common use. However, Fig. 17 illustrates five sizes of milling fixture keys and these are made out of square drill rod. This is a very simple form and is widely used throughout the industry. There are a number of other sizes of keys used in making tools and these are also shown in Fig. 17.

Studs. In designing jigs and fixtures it becomes necessary in many instances to use studs for attaching clamps and other parts to jigs and fixtures. Therefore, standards have been worked out. Fig. 18 illustrates a standard form of stud. Another type of stud that is generally used on jigs, fixtures, special machines, etc., is shown in Fig. 19. This chart shows the variations in sizes that can be adopted as a definite standard, and the tool designer should try to stay within these specifications.

Dowel Pins. In designing jigs, fixtures, or special machines where a great many detail parts are assembled and in some particular cases where unit assembly is necessary, removable pilot pins are desirable. Fig. 20 illustrates a form of removable dowel pin. These are generally made from drill rod and are hardened and ground. A thread is cut on the large end and the dowel pin is driven in the same way as the regular type of pin. In order to withdraw the pin easily, a nut is screwed on the threaded end of the pin and the pressure applied allows withdrawal of the pin from the part. In some instances it would be impossible to drive out the dowel pin from the other side of the work. Two sizes are shown in Fig. 20; other sizes could be standardized if desired.

T Screws. In designing leaf-type jigs it is necessary to use some means for locking the leaf or jig plate to the jig body after the work has been inserted. Therefore **T** screws, Fig. 21, are in general use. A standard similar to the one shown on the chart accompanying Fig. 21 has been worked out in some plants.

Eyebolts. On some types of leaf jigs it is necessary to have an eyebolt that is attached to a bracket that is either cast integral with the jig body or, in case of the built-up jig, made of steel plates.

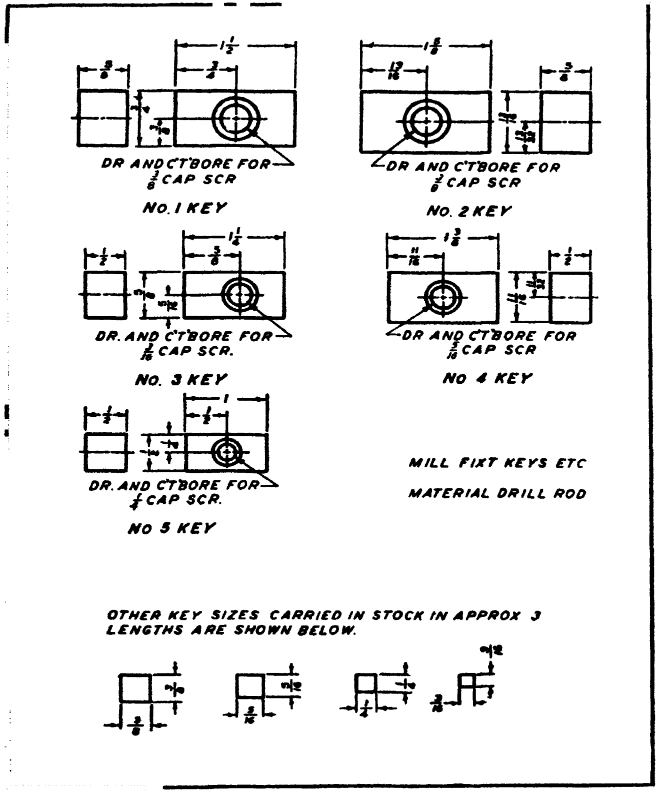
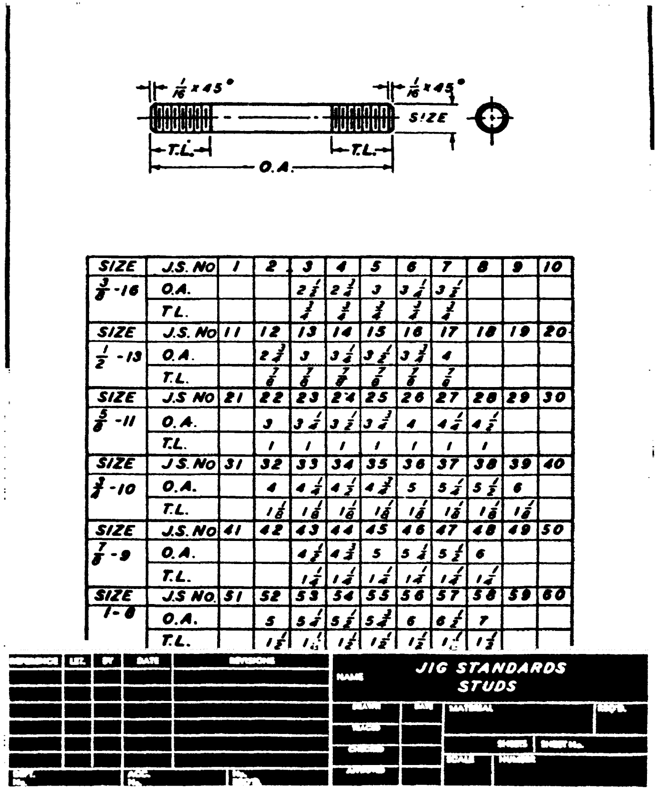
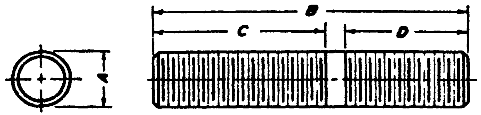

DR AND C'T'BORE FOR $\frac{3}{8}$ CAP SCR
NO. 1 KEY
DR AND C'T'BORE FOR $\frac{3}{8}$ CAP SCR
NO. 2 KEY
DR. AND C'T'BORE FOR $\frac{5}{16}$ CAP SCR.
NO. 3 KEY
DR AND C'T'BORE FOR $\frac{5}{16}$ CAP SCR
NO 4 KEY
DR. AND C'T'BORE FOR $\frac{1}{4}$ CAP SCR.
NO 5 KEY
MILL FIXT KEYS ETC
MATERIAL DRILL ROD
OTHER KEY SIZES CARRIED IN STOCK IN APPROX 3 LENGTHS ARE SHOWN BELOW.

Fig. 17



SIZE	J.S. NO	1	2	3	4	5	6	7	8	9	10
$\frac{3}{8}$-16	O.A.			$2\frac{1}{2}$	$2\frac{3}{4}$	3	$3\frac{1}{4}$	$3\frac{1}{2}$			
	T.L.			$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$			
SIZE	J.S. NO	11	12	13	14	15	16	17	18	19	20
$\frac{1}{2}$-13	O.A.		$2\frac{3}{4}$	3	$3\frac{1}{4}$	$3\frac{1}{2}$	$3\frac{3}{4}$	4			
	T.L.		$\frac{7}{8}$	$\frac{7}{8}$	$\frac{7}{8}$	$\frac{7}{8}$	$\frac{7}{8}$	$\frac{7}{8}$			
SIZE	J.S NO	21	22	23	24	25	26	27	28	29	30
$\frac{5}{8}$-11	O.A.		3	$3\frac{1}{4}$	$3\frac{1}{2}$	$3\frac{3}{4}$	4	$4\frac{1}{4}$	$4\frac{1}{2}$		
	T.L.		1	1	1	1	1	1	1		
SIZE	J.S. NO	31	32	33	34	35	36	37	38	39	40
$\frac{3}{4}$-10	O.A.		4	$4\frac{1}{4}$	$4\frac{1}{2}$	$4\frac{3}{4}$	5	$5\frac{1}{4}$	$5\frac{1}{2}$	6	
	T.L.		$1\frac{1}{8}$	$1\frac{1}{8}$	$1\frac{1}{8}$	$1\frac{1}{8}$	$1\frac{1}{8}$	$1\frac{1}{8}$	$1\frac{1}{8}$	$1\frac{1}{8}$	
SIZE	J.S. NO	41	42	43	44	45	46	47	48	49	50
$\frac{7}{8}$-9	O.A.			$4\frac{1}{2}$	$4\frac{3}{4}$	5	$5\frac{1}{4}$	$5\frac{1}{2}$	6		
	T.L.			$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$		
SIZE	J.S NO.	51	52	53	54	55	56	57	58	59	60
1-8	O.A.		5	$5\frac{1}{4}$	$5\frac{1}{2}$	$5\frac{3}{4}$	6	$6\frac{1}{2}$	7		
	T.L.		$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$		

Fig.



NUT END STUD END

STUDS

MATERIAL S.A.E. 3135 ST

DIA-A	B	C	D
$\frac{1}{2}$-13	3	$1\frac{1}{2}$	$1\frac{1}{16}$
	4	$1\frac{1}{2}$	$1\frac{1}{16}$
	5	$1\frac{1}{2}$	$1\frac{1}{16}$
	6	$1\frac{1}{2}$	$1\frac{1}{16}$
	7	$1\frac{1}{2}$	$1\frac{1}{16}$

DIA-A	B	C	D
$\frac{5}{8}$-11	4	$1\frac{7}{8}$	$1\frac{5}{16}$
	5	$1\frac{7}{8}$	$1\frac{5}{16}$
	6	$1\frac{7}{8}$	$1\frac{5}{16}$
	7	$1\frac{7}{8}$	$1\frac{5}{16}$
	8	$1\frac{7}{8}$	$1\frac{5}{16}$
	9	$1\frac{7}{8}$	$1\frac{5}{16}$

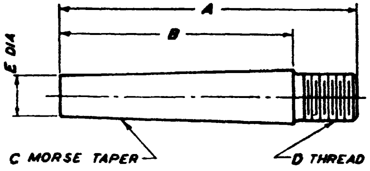
DIA-A	B	C	D
$\frac{3}{4}$-10	4	$2\frac{1}{4}$	$1\frac{9}{16}$
	5	$2\frac{1}{4}$	$1\frac{9}{16}$
	6	$2\frac{1}{4}$	$1\frac{9}{16}$
	7	$2\frac{1}{4}$	$1\frac{9}{16}$
	8	$2\frac{1}{4}$	$1\frac{9}{16}$
	9	$2\frac{1}{4}$	$1\frac{9}{16}$

DIA-A	B	C	D
$\frac{7}{8}$-9	5	$2\frac{5}{8}$	$1\frac{13}{16}$
	6	$2\frac{5}{8}$	$1\frac{13}{16}$
	7	$2\frac{5}{8}$	$1\frac{13}{16}$
	8	$2\frac{5}{8}$	$1\frac{13}{16}$
	9	$2\frac{5}{8}$	$1\frac{13}{16}$
	10	$2\frac{5}{8}$	$1\frac{13}{16}$
	11	$2\frac{5}{8}$	$1\frac{13}{16}$
	12	$2\frac{5}{8}$	$1\frac{13}{16}$

DIA-A	B	C	D
1-8	5	$2\frac{3}{4}$	$2\frac{1}{16}$
	6	$2\frac{3}{4}$	$2\frac{1}{16}$
	7	$2\frac{3}{4}$	$2\frac{1}{16}$
	8	$2\frac{3}{4}$	$2\frac{1}{16}$
	9	$2\frac{3}{4}$	$2\frac{1}{16}$
	10	$2\frac{3}{4}$	$2\frac{1}{16}$
	11	$2\frac{3}{4}$	$2\frac{1}{16}$
	12	$2\frac{3}{4}$	$2\frac{1}{16}$

LENGTH C = 3 × DIA OF STUD EXCEPT 1 DIA WHICH IS $2\frac{3}{4}$ × DIA
LENGTH D = $1\frac{1}{2}$ × DIA OF STUD + HEIGHT OF JAM NUT

Fig. 19

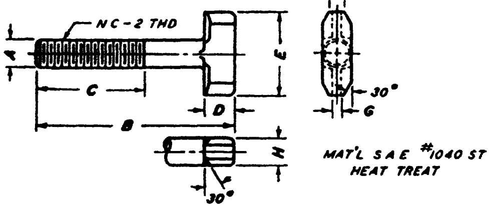


REMOVABLE DOWEL NO.	TAPER PER FOOT	A	B	C	D	E
1	600	$2\frac{7}{8}$	$2\frac{3}{8}$	1	$\frac{3}{8}$-16	.369
2	602	$3\frac{13}{16}$	3	2	$\frac{5}{8}$-11	.572

REFERENCE LET. BY DATE REVISIONS
DEPT. No. ACC. No. No. REQ'D.
NAME REMOVABLE DOWEL PINS
DRAWN DATE MATERIAL MOD'L.
TRACED
CHECKED SHEETS SHEET No.
APPROVED SCALE NUMBER

Fig 20

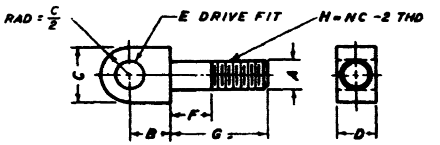
JIG STANDARDS
T SCREWS



MAT'L S.A.E #1040 ST
HEAT TREAT

J.S. NO.	A	B	C	D	E	F	G	H
100	3/8-16	2	1 3/8	1/2	1 1/8	3/16	1/8	3/8
101	3/8-16	2 1/2	1 3/8	1/2	1 1/8	3/16	1/8	3/8
102	3/8-16	3	1 3/8	1/2	1 1/8	3/16	1/8	3/8
103								
105	1/2-13	2 1/2	1 1/2	5/8	1 1/4	1/4	1/8	1/2
106	1/2-13	2 3/4	1 1/2	5/8	1 1/4	1/4	1/8	1/2
107	1/2-13	3	1 1/2	5/8	1 1/4	1/4	1/8	1/2
108	1/2-13	3 1/4	1 1/2	5/8	1 1/4	1/4	1/8	1/2
109	1/2-13	3 1/2	1 1/2	5/8	1 1/4	1/4	1/8	1/2
110								
111	5/8-11	3 1/4	1 7/8	3/4	1 7/16	1/4	3/16	5/8
112	5/8-11	3 1/2	1 7/8	3/4	1 7/16	1/4	3/16	5/8
113	5/8-11	4	1 7/8	3/4	1 7/16	1/4	3/16	5/8
114	5/8-11	4 1/2	1 7/8	3/4	1 7/16	1/4	3/16	5/8
115	5/8-11	5	1 7/8	3/4	1 7/16	1/4	3/16	5/8
116								
117	3/4-10	4	2 3/8	7/8	1 5/8	3/8	3/16	3/4
118	3/4-10	4 1/2	2 3/8	7/8	1 5/8	3/8	3/16	3/4
119	3/4-10	5	2 3/8	7/8	1 5/8	3/8	3/16	3/4
120	3/4-10	5 1/2	2 3/8	7/8	1 5/8	3/8	3/16	3/4

Fig. 21



MAT'L. S.A.E #1040 ST
HEAT TREAT

J.S. NO.	A	B	C	D	E	F	G	H
205	3/8	1/2	3/4	1/2	3/8	1/2	1 1/4	3/8-16
206	3/8	1/2	3/4	1/2	3/8	1/2	1 1/2	
207	3/8	1/2	3/4	1/2	3/8	1	2	
208	3/8	1/2	3/4	1/2	3/8	1	2 1/2	
209	1/2	5/8	1	5/8	1/2	5/8	1 1/2	1/2-13
210	1/2	5/8	1	5/8	1/2	5/8	2	
211	1/2	5/8	1	5/8	1/2	5/8	2 1/2	
212	1/2	5/8	1	5/8	1/2	1	3	
213	5/8	3/4	1 1/4	3/4	5/8	3/4	2	5/8-11
214	5/8	3/4	1 1/4	3/4	5/8	3/4	2 1/2	
215	5/8	3/4	1 1/4	3/4	5/8	3/4	3	
216	5/8	3/4	1 1/4	3/4	5/8	3/4	3 1/2	
217	3/4	7/8	1 1/2	7/8	3/4	7/8	2	3/4-10
218	3/4	7/8	1 1/2	7/8	3/4	7/8	2 1/2	
219	3/4	7/8	1 1/2	7/8	3/4	7/8	3	
220	3/4	7/8	1 1/2	7/8	3/4	7/8	3 1/2	

REFERENCE	LTR.	BY	DATE	REVISIONS

NAME **JIG STANDARDS**
EYEBOLTS

MATERIAL

Fig. 22

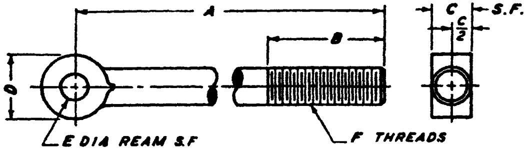
The bracket would be attached by means of welding or screws. These eyebolts hold the jig leaf in place by the use of a knurled hand nut or a thumbscrew, depending on the size. The eyebolts are shown on Fig. 22 and the chart shows the various sizes that could be standardized to facilitate design.

Another type of eyebolt, Fig. 23, has been adopted as standard in some plants where the type of work requires extra length. A chart accompanies this illustration to show the variation in sizes.

Drill-Thru Locator Pins. In a great many plants it is necessary to drill pin or screw holes at right angles to a bore in order to fasten the pulley, collar or stop on a shaft. Therefore, locator pins that are attached to angle plates have been designed to handle these jobs. In these drill-thru locator pins, Fig. 24, the smaller sizes have a carefully drilled hole with a countersink in it to permit the entrance of a drill to the guide hole. The larger sizes are designed so that a hardened and ground drill bushing can be inserted. The chart accompanies Fig. 24 to show the possibilities of standardization on an item of this kind.

Seat Washers. When attaching clamps to jigs and fixtures, particularly where the clamp is acting on an unfinished surface, it is desirable to have a spherical seat in the clamp in order that a spherical seat washer can be used to take care of any misalignment. Fig. 25 shows the design of several sizes. There are many other applications of these spherical seat washers on floating and equalizing clamps.

Clamps. These have a wide variety of uses on jigs and fixtures. Many different types of clamps are designed to do particular jobs; that is, to hold the work securely in the jig or fixture to prevent movement of the part being machined. The most common type is the plain clamp, Fig. 26. These are usually made of mild steel, S.A.E. 1020, then carburized and hardened. The clamp illustrated in Fig. 26 is made of 1040 steel, heat-treated to give it toughness, and the end where it comes in contact with the work is given a coating of Stellite to resist abrasion caused by constant use. Note that both sides of the end of this type of clamp have been given a coating of Stellite so that the clamp can be used on either side, or when one side becomes worn the other side can be used without removing the clamp from the jig or fixture. The chart shows the



NOTE: MATERIAL 3135 ST

THESE EYEBOLTS ARE FORGED IN 12" LENGTHS

BOLT NO	A	B	C	D	E	F
	TO SUIT					
1	TO SUIT	TO SUIT	1/2	7/8	3/8	1/2-13NC
2	TO SUIT	TO SUIT	5/8	1	1/2	5/8-11NC
3	TO SUIT	TO SUIT	3/4	1 1/4	5/8	3/4-10NC

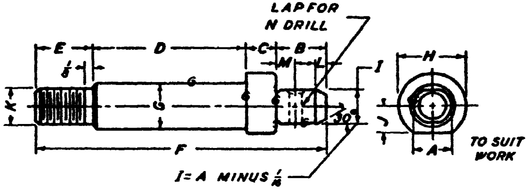
REFERENCE	LTR.	BY	DATE	REVISIONS
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

DEPT. No. ACC. No. No. REQ'D.

NAME EYEBOLTS

DRAWN DATE MATERIAL REQ'D
TRACED
CHECKED SHEETS SHEET No.
APPROVED SCALE NUMBER

Fig. 23



H - 1 DIA OR LESS, T S HDN AND GRD.
H - OVER 1 DIA, M S L HDN AND GRD

90° C'T'SINK ENTERING END OF DRILL HOLE - 1/32 DEEP

J S. NO	B	C	D	E	F	G	H	J	K	L	M	N
271	1/2	3/8	1 3/8	11/16	2 15/16	1/2	7/8	3/8	3/8-16	1/8	TO SUIT	TO SUIT
272	11/16	3/8	1 3/8	11/16	2 15/16	1/2	7/8	3/8	3/8-16	1/8	"	"
273	5/8	1/2	1 3/4	13/16	3 11/16	5/8	1	7/16	1/2-13	3/16	"	"
274	13/16	1/2	1 3/4	13/16	3 7/8	5/8	1	7/16	1/2-13	3/16	"	"
PINS BELOW HAVE DRILL BUSHINGS-MAKE DIM N FOR BUSHINGS AS PER DIMENSION SHOWN												
275	3/4	1/2	2 1/8	15/16	4 5/16	3/4	1 1/4	1/2	5/8-11	3/16	TO SUIT	5/16
276	15/16	1/2	2 1/8	15/16	4 1/2	3/4	1 1/4	1/2	5/8-11	3/16	"	5/16
277	1	5/8	2 3/8	15/16	4 15/16	7/8	1 3/8	9/16	5/8-11	1/4	"	5/16
278	1 1/2	5/8	2 3/8	1 1/16	5 9/16	1	1 1/2	5/8	3/4-10	1/4	"	1/2

REFERENCE	LTR.	BY	DATE	REVISIONS

DEPT. No. ACC. No. No. REQ'D.

NAME JIG STANDARDS DRILL-THRU-LOCATOR PINS

DRAWN DATE MATERIAL REQ'D.
TRACED
CHECKED SHEETS SHEET No.
APPROVED SCALE NUMBER

Fig. 24

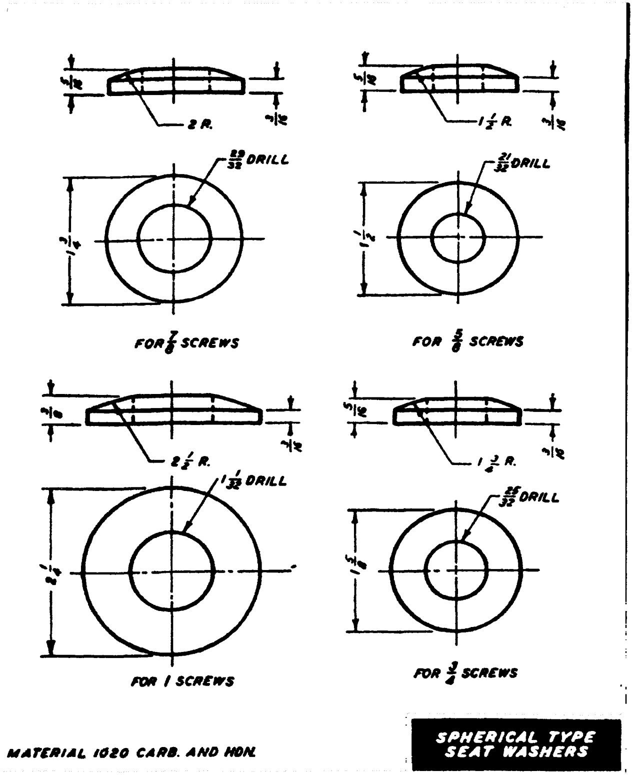
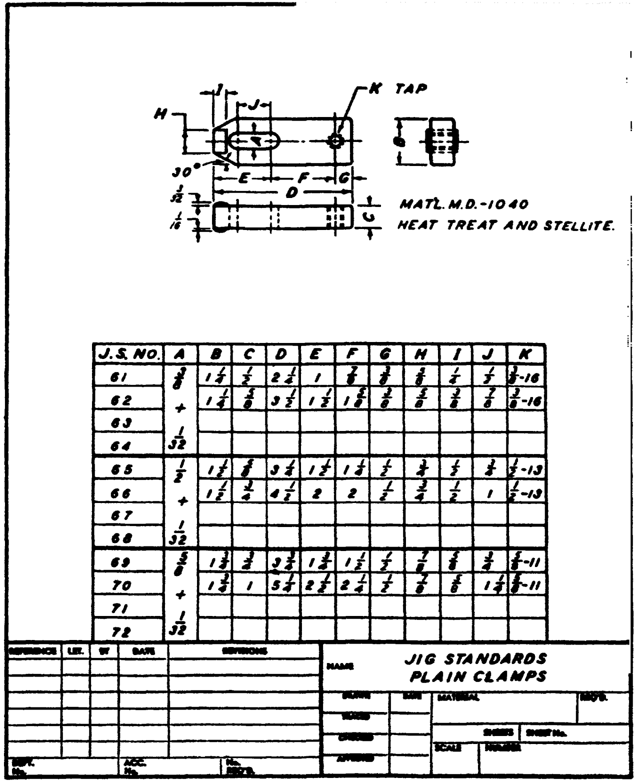
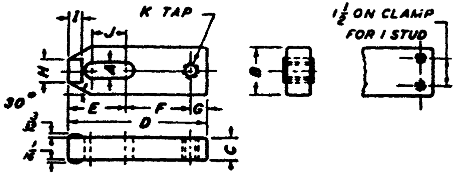


Fig. 25



J.S. NO.	A	B	C	D	E	F	G	H	I	J	K
61	3/8 + 1/32	1 1/4	1/2	2 1/4	1	7/8	3/8	5/8	1/4	1/2	3/8-16
62		1 1/4	5/8	3 1/2	1 1/2	1 5/8	3/8	5/8	3/8	7/8	3/8-16
63											
64											
65	1/2 + 1/32	1 1/2	5/8	3 1/4	1 1/2	1 1/4	1/2	3/4	1/2	3/4	1/2-13
66		1 1/2	3/4	4 1/2	2	2	1/2	3/4	1/2	1	1/2-13
67											
68											
69	5/8 + 1/32	1 3/4	3/4	3 3/4	1 3/4	1 1/2	1/2	7/8	5/8	3/4	5/8-11
70		1 3/4	1	5 1/4	2 1/2	2 1/4	1/2	7/8	5/8	1 1/4	5/8-11
71											
72											

Fig. 26

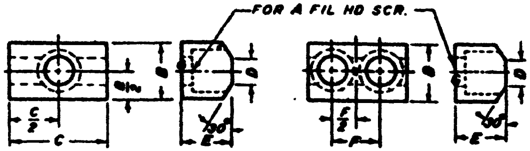


MAT'L. M D-1040
HEAT TREAT AND STELLITE

J.S. NO.	A	B	C	D	E	F	G	H	I	J	K
73	$\frac{3}{4}+\frac{1}{32}$	2	1	$4\frac{7}{8}$	$2\frac{1}{4}$	2	$\frac{5}{8}$	1	$\frac{5}{8}$	$1\frac{1}{4}$	$\frac{3}{4}$-10
74		2	$1\frac{1}{4}$	$5\frac{7}{8}$	$2\frac{3}{4}$	$2\frac{1}{2}$	$\frac{5}{8}$	1	$\frac{5}{8}$	$1\frac{1}{2}$	$\frac{3}{4}$-10
75											
76											
77	$\frac{7}{8}+\frac{1}{32}$	$2\frac{1}{4}$	$1\frac{1}{4}$	6	$2\frac{3}{4}$	$2\frac{1}{2}$	$\frac{3}{4}$	$1\frac{1}{4}$	$\frac{5}{8}$	$1\frac{1}{4}$	$\frac{7}{8}$-9
78		$2\frac{1}{4}$	$1\frac{1}{2}$	$7\frac{1}{4}$	$3\frac{1}{4}$	$3\frac{1}{4}$	$\frac{3}{4}$	$1\frac{1}{4}$	$\frac{5}{8}$	$1\frac{3}{4}$	$\frac{7}{8}$-9
79											
80											
81	$1+\frac{1}{32}$										
82		$2\frac{1}{2}$	$1\frac{1}{2}$	$7\frac{1}{2}$	$3\frac{1}{2}$	$3\frac{3}{8}$	$\frac{5}{8}$	$1\frac{1}{2}$	NOT ON CLAMP	2	$\frac{1}{2}$-13
83											
84											

NAME JIG STANDARDS PLAIN CLAMPS

Fig. 27



MAT'L. M.D. 1015
C.H. AND G.

J.S. NO.	A	B	C	D	E	F
141	[illegible]	$\frac{3}{8}$	$1\frac{1}{4}$	$\frac{3}{8}$	[illegible]	
142	$\frac{1}{2}$	$\frac{3}{4}$	$1\frac{1}{4}$	$\frac{1}{2}$	$1\frac{1}{8}$	
143	$\frac{1}{2}$	1	$1\frac{3}{8}$	$\frac{1}{2}$	$\frac{3}{4}$	
144	$\frac{1}{2}$	1	$1\frac{1}{2}$	$\frac{1}{2}$	$1\frac{1}{4}$	
145	[illegible]	1	$1\frac{3}{4}$	$\frac{5}{8}$	$\frac{7}{8}$	
146	$\frac{5}{8}$	1	$1\frac{3}{4}$	$\frac{5}{8}$	$1\frac{1}{2}$	
147	$\frac{3}{4}$	$1\frac{1}{4}$	2	$\frac{3}{4}$	$1\frac{1}{8}$	
148	$\frac{3}{4}$	$1\frac{1}{4}$	2	$\frac{3}{4}$	$1\frac{3}{4}$	
149	$\frac{7}{8}$	$1\frac{1}{2}$	$2\frac{1}{4}$	$\frac{7}{8}$	$1\frac{1}{2}$	
150	$\frac{7}{8}$	$1\frac{1}{2}$	$2\frac{1}{4}$	$\frac{7}{8}$	$2\frac{1}{4}$	
151	$\frac{1}{2}$	$1\frac{1}{4}$	$2\frac{1}{2}$	$\frac{5}{8}$	$1\frac{3}{4}$	$1\frac{1}{2}$
152	$\frac{5}{8}$	$1\frac{1}{4}$	$2\frac{1}{2}$	$\frac{5}{8}$	$2\frac{1}{2}$	

NAME JIG STANDARDS CLAMP HEELS

Fig. 28

various sizes that can be adapted to the needs of the particular plant in which they would be used.

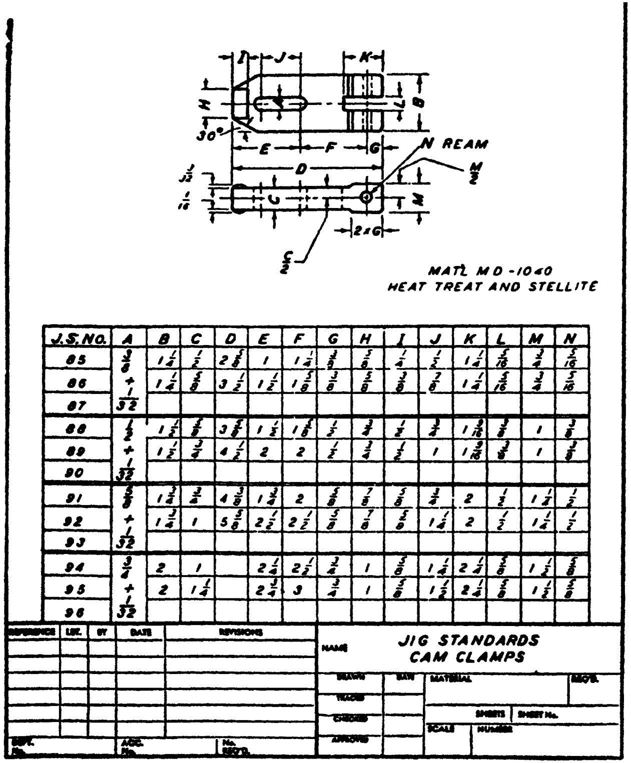
Fig. 27, with chart, shows a larger size of the same clamp shown in Fig. 26, but on the larger sizes two heels may be attached to the rear end of the clamp. This permits a 3-point bearing to equalize the clamping action.

Clamp heels, Fig. 28, are used with the clamp shown in Fig. 27. This is good design and construction. Cam clamps, Fig. 29, have a wide use on jigs and fixtures. Note that each one of these clamps has been given a number; this saves time in designing jigs and fixtures, as it is only necessary to refer to the number of the particular clamp desired; it is not necessary to make a drawing, especially when the tools are being fabricated in the company's plant. A set of standard sheets are on file in the tool room, and these can be referred to when it is necessary to make up these clamps. Another good feature is that, when there is not much work in the tool room, apprentice boys can make these various standard items so they will be available when it is necessary to build jigs and fixtures for production.

Clamp cams, Fig. 30, are designed in a variety of types. The one illustrated shows the type of clamp cam that can be used in conjunction with the clamps illustrated by Fig. 29. Note that this clamp cam can be operated from either right or left instead of one direction as is sometimes the case. The chart shows the way these clamp cams have been standardized.

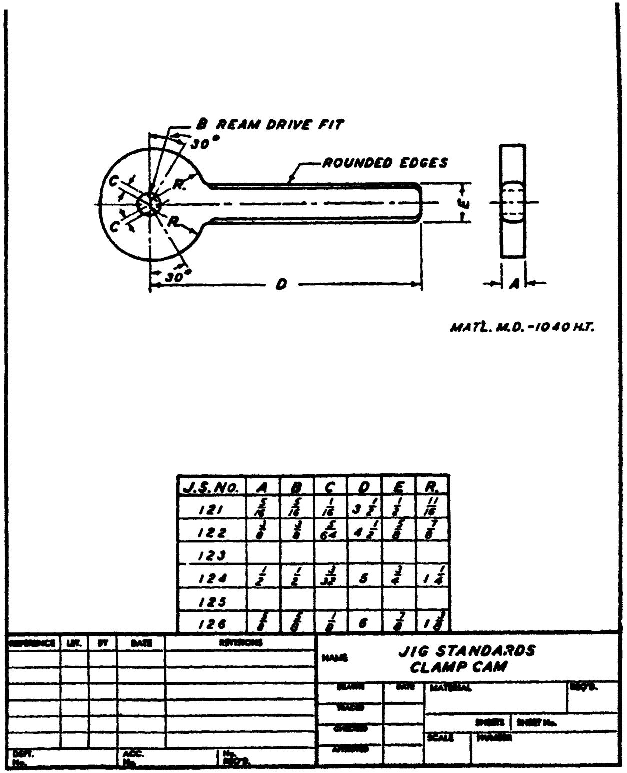
A clamp and cam clamp of another type are illustrated in Fig. 31. This shows the assembly and the specifications that can be placed on the tool drawing for the guidance of the toolmaker. Detail *29*, the clamp, is dimensioned to suit the needs of the particular job. Note that this clamp is forged to make the heel integral with the clamp. Fig. 32 illustrates the dimensions of a cam.

Another type of cam assembly, Fig. 33, shows a straight clamp with a slot in the rear end for attaching the cam clamp, with specifications that are placed on the drawing for guidance of the tool room in making this clamp. The clamp itself, detail *27*, is dimensioned to suit the needs of the jig or fixture on which it is to be used. The cam, Fig. 34, has detailed information as to dimensions, layout of the cam section, etc. This cuts down the designing time,



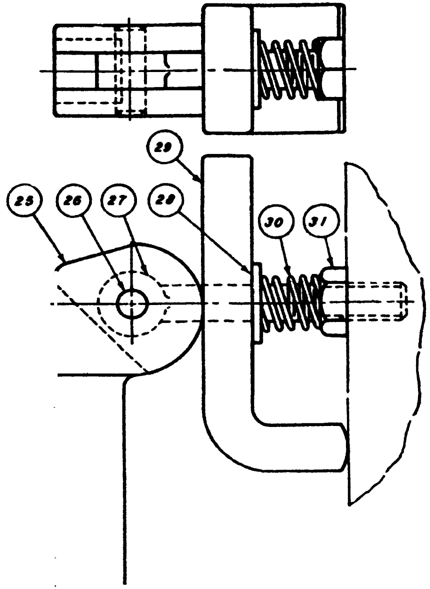
J.S. NO.	A	B	C	D	E	F	G	H	I	J	K	L	M	N
85	3/8 + 1/32	1 1/4	1/2	2 5/8	1	1 1/4	3/8	5/8	1/4	1/2	1 1/4	5/16	3/4	5/16
86		1 1/4	5/8	3 1/2	1 1/2	1 5/8	3/8	5/8	3/8	7/8	1 1/4	5/16	3/4	5/16
87														
88	1/2 + 1/32	1 1/2	5/8	3 5/8	1 1/2	1 5/8	1/2	3/4	1/2	3/4	1 3/16	3/8	1	3/8
89		1 1/2	3/4	4 1/2	2	2	1/2	3/4	1/2	1	1 9/16	3/8	1	3/8
90														
91	5/8 + 1/32	1 3/4	3/4	4 3/8	1 3/4	2	5/8	7/8	5/8	3/4	2	1/2	1 1/4	1/2
92		1 3/4	1	5 5/8	2 1/2	2 1/2	5/8	7/8	5/8	1 1/4	2	1/2	1 1/4	1/2
93														
94	3/4 + 1/32	2	1		2 1/4	2 1/2	3/4	1	5/8	1 1/4	2 1/4	5/8	1 1/2	5/8
95		2	1 1/4		2 3/4	3	3/4	1	5/8	1 1/2	2 1/4	5/8	1 1/2	5/8
96														

Fig. 29



J.S. NO.	A	B	C	D	E	R.
121	5/16	5/16	1/16	3 1/2	1/2	11/16
122	3/8	3/8	5/64	4 1/2	5/8	7/8
123						
124	1/2	1/2	3/32	5	3/4	1 1/4
125						
126	5/8	5/8	1/8	6	7/8	1 3/8

Fig. 30

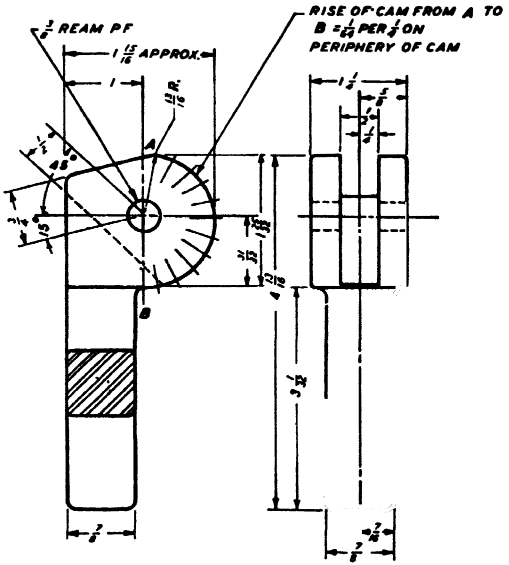


SPECIFY DET'S. ON TOOL DR'W'G. AS SHOWN

DET. NO.	NO. REQ'D.	DESCRIPTION	MAT'L.
25	1	CAM	ST'D.
26	1	3/8 X 1¼	DR RD.
27	1	#1 EYEBOLT 3½ LG. 1¼ THD.	ST'D.
28	1	½ STD WASHER	ST'D.
29	1	CLAMP	1020
30	1	SPRING TO SUIT	ST'D.
31	1	½-13 HEX JAM NUT	ST'D.

CAM ASSEMBLY

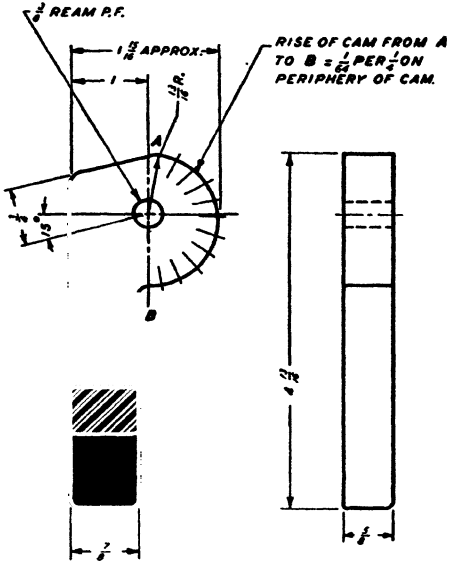
Fig. 31



MATERIAL S A E 1020 CYAN. HDN.

CAM DETAIL

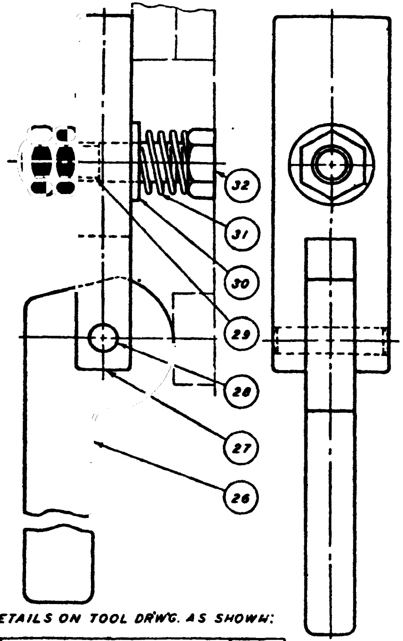
Fig. 32



MATERIAL S A E 1020-CYAN

CAM DETAIL

Fig. 34

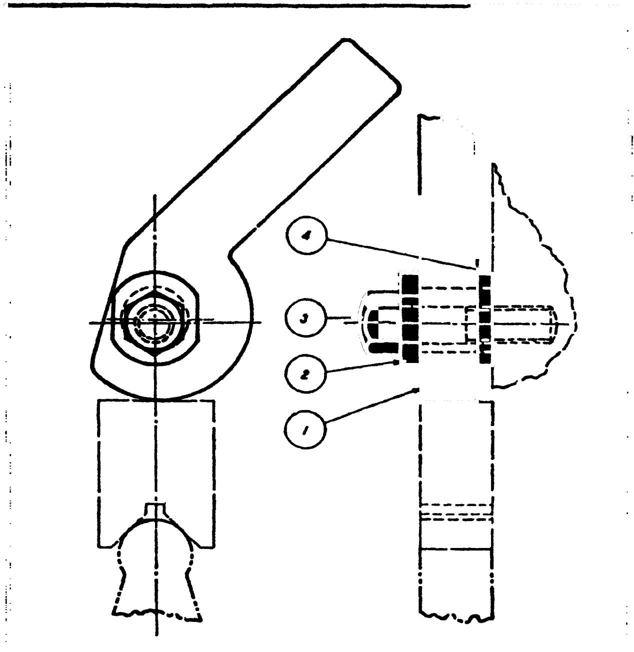


SPECIFY DETAILS ON TOOL DR'W'G. AS SHOWN:

NO.	NO. REQ'D.	DESCRIPTION	MAT'L.
26	1	CAM	ST'D.
27	1		
28	1	3/8 DIA. X 1½ LONG	
29	1	½-13 N.C. X 4 LONG STUD	
[illegible]	1	STD. ½ WASHER	
31	1	SPRING TO SUIT	
[illegible]	[illegible]	½-13 HEX. JAM NUT	

CAM ASSEMBLY

Fig. 33



SPECIFY DETAILS ON TOOL DRW'G AS SHOWN:

DET. NO.	NO. REQ'D.	DESCRIPTION	MAT'L.
1	1	CAM	STD.
2	1	#1 CAM BUSHING	STD.
3	1	1/2-13 X 2 1/4 HEX. HD. CAP SCR.	STK.
4	1	1 1/4 O.D. X [illegible] I.D. X [illegible] THICK	S.A.E. 10[illegible] ST.

CAM ASSEMBLY

Fig. 35

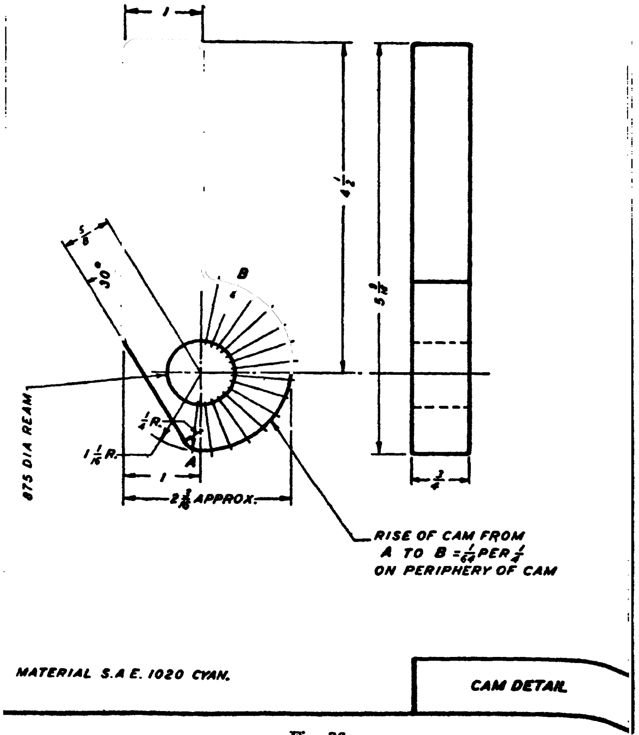

1
4 1/2
5 9/16
3/4
5/8
30°
B
A
1/4 R.
1 1/16 R.
1
2 3/16 APPROX.
.875 DIA REAM
RISE OF CAM FROM A TO B = 1/64 PER 1/4 ON PERIPHERY OF CAM
MATERIAL S.A.E. 1020 CYAN.
CAM DETAIL

Fig. 36

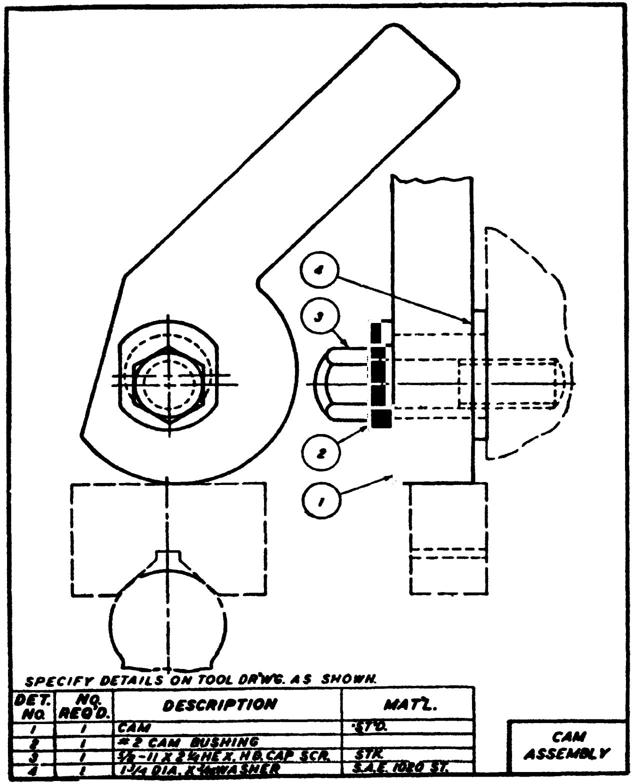
particularly when a plant is hiring new men, as this information is readily available on the standard sheets.

Cam clamps, as shown in Fig. 35, are used in conjunction with sliding vees to locate work properly in the jig and fixture. This type of cam is very generally used, and farther on in this book the use of these clamping cams will be further illustrated. Fig. 36 shows the detailed information on this type of cam; the dimensions given here can be changed to suit the needs of individual plants.

Fig. 37 is a larger type of cam clamp, also to be used with a sliding vee or to clamp a part directly in a jig or fixture. The cam itself is usually made out of mild steel, S.A.E. 1020, carburized and hardened to resist abrasion due to constant wear. After hardening, the center hole is lapped to permit the insertion of a bushing. Fig. 38 illustrates the details of a cam. The sizes shown here can be changed to suit individual jobs. Fig. 39 shows the detailed information on eccentric bushings used in conjunction with the cam clamps as shown by Figs. 37 and 38.

Cam Latches. On box jigs and certain types of fixtures it is necessary to use a cam latch, Fig. 40. This latch locks the jig leaf in place, or a separate swing plate on a fixture. It is very fast and positive in action. The cam latch is made out of S.A.E. 1020 and is cyanide-hardened to prevent wear.

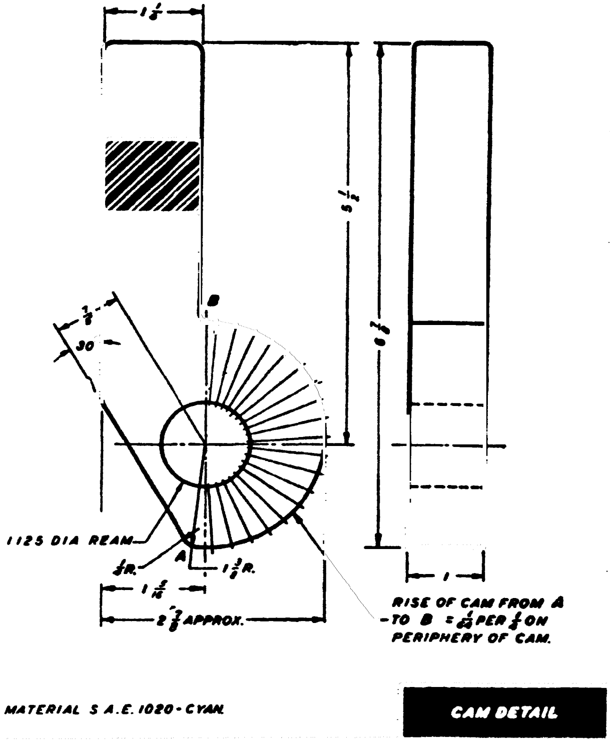
Stands. In designing indexing and turnover jigs, trunnion brackets or stands are used. In some plants the stand is usually designed individually to suit the needs of the particular job on hand. This is very expensive as it means a new pattern in each instance. However, in some plants it was found by analysis that standards could be adopted that would suit the needs of practically all requirements for indexing and turnover jigs. Fig. 41 illustrates a stand with an 11″ swing. A permanent pattern is made and a quantity of these stands are ordered from the foundry so as to be available in the tool room when required. The design shown in Fig. 41 is capable of wide use. Note on this drawing that in addition to the four bolt holes to fasten the stand on either end of the jig or fixture base, two ⅝″ reamed holes are included for dowel pins. This permits the accurate location of this stand at the proper position for the trunnions on the jig base. These stands are usually made of a gray iron casting.



SPECIFY DETAILS ON TOOL DR'WG. AS SHOWN.

DET. NO.	NO. REQ'D.	DESCRIPTION	MAT'L.
1	1	CAM	STD.
2	1	#2 CAM BUSHING	
3	1	5/8-11 X 2¼ HEX. HD. CAP SCR.	STK.
4	1	1¼ DIA. X 3/16 WASHER	S.A.E. 1020 ST.

Fig. 37



RISE OF CAM FROM A TO B = $\frac{1}{64}$ PER $\frac{1}{8}$ ON PERIPHERY OF CAM.

MATERIAL S.A.E. 1020-CYAN.

Fig. 38

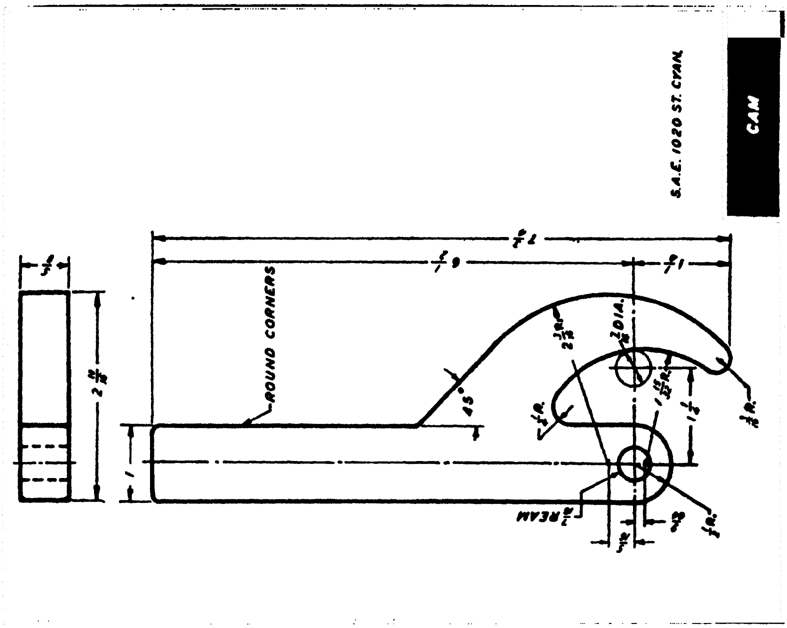
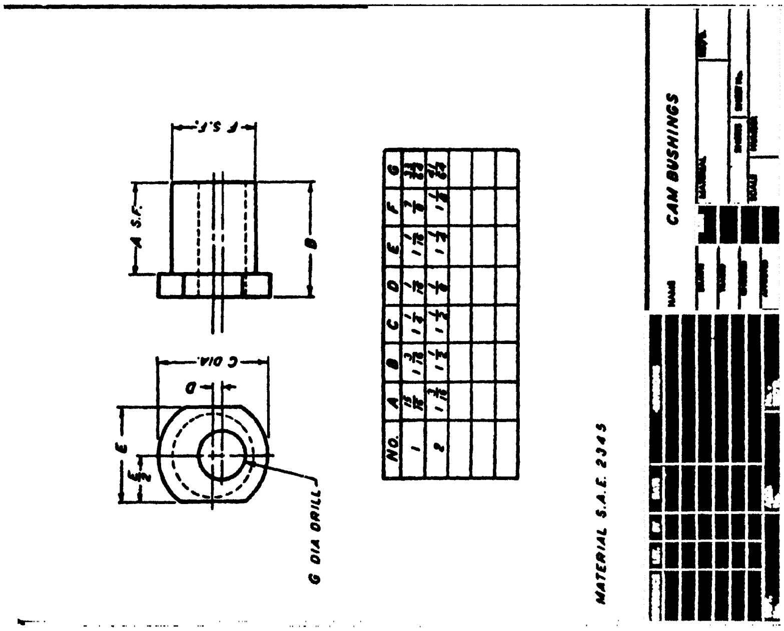


Fig. 40



NO.	A	B	C	D	E	F	G
1	15/16	1 3/16	1 1/4	1/16	1 1/16	7/8	33/64
2	1 3/16	1 1/4	1 1/2	1/8	1 1/4	1 1/8	21/64

Fig. 39

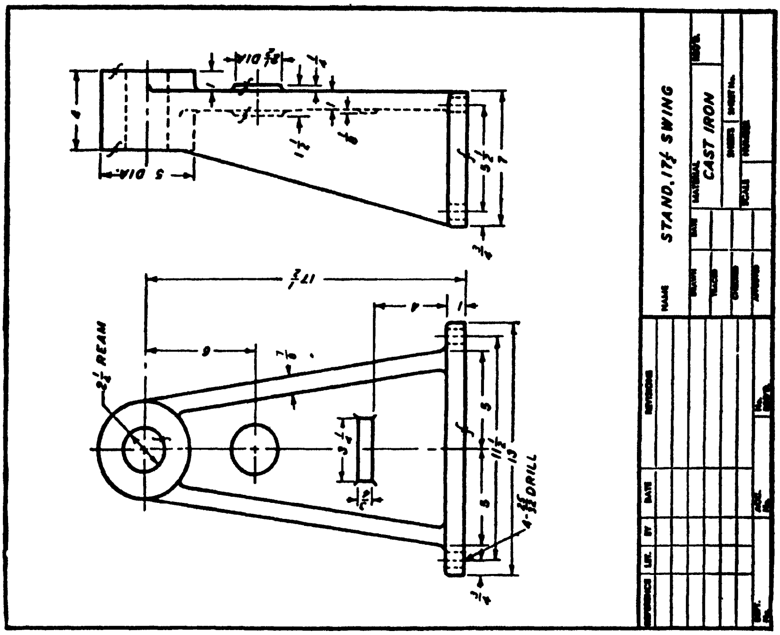

STAND, 17½ SWING
CAST IRON
2½ REAM
4-$\frac{25}{32}$ DRILL
5 DIA
17½
9
13
11½
5
5
5½
7
4
NAME
MATERIAL
SCALE
REVISIONS

Fig. 42

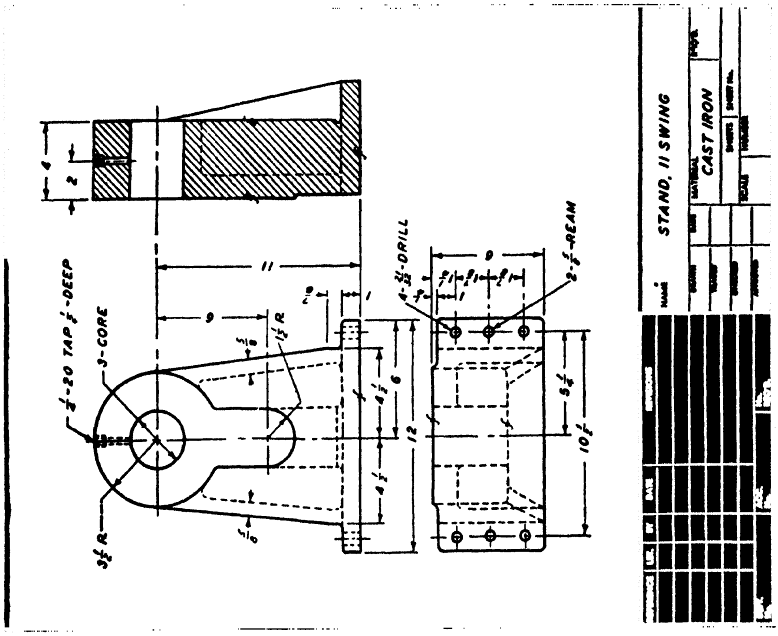

STAND, 11 SWING
CAST IRON
½-20 TAP ½-DEEP
3-CORE
3½ R
1½ R
4-$\frac{21}{32}$-DRILL
2-$\frac{5}{8}$-REAM
11
9
12
6
4½
4½
10½
5½
4
2
NAME
MATERIAL
SCALE
REVISIONS

Fig. 41

Fig. 42 illustrates a stand with a 17½″ swing. This design is somewhat different from that shown in Fig. 42 and is used for much larger jigs and fixtures. These stands are sometimes termed *pilot bushing brackets* because in some boring operations it is necessary to have pilot bushings on both sides of the fixture to guide the boring bar, particularly in accurate boring work where the fixture is designed so that the machine is used only for power, and all the necessary accuracy is built into the fixture and into the boring bar.

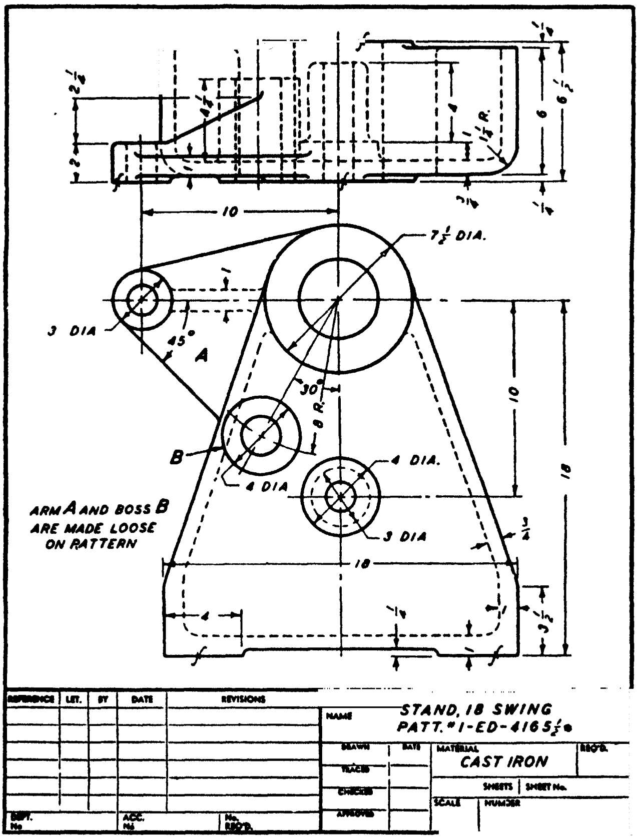


Fig. 43

Another variation in stands for indexing and turnover jigs is illustrated by Fig. 43. This has an 18″ swing, and note that the arm *A* and boss *B* are made loose on the pattern so they can readily be removed to suit the needs of the average job. This extra arm and boss could be used on the stand where it might be necessary to have additional indexing points or for support in the machining operation.

Fig. 43A illustrates the use of these stands or trunnion brackets on a fixture for drilling various holes in a large gear. It will be noted that there are a number of loose parts to be used in this turnover jig. This type of jig is used under a multiple-spindle drilling machine. Two pieces are drilled at one time, and, while this operation is going on, the previously drilled pieces are unloaded and new pieces inserted for machining. A fixture of this type is very efficient, as it saves considerable time in loading, unloading and machining.

Another type of stand is illustrated by Fig. 43B which shows an indexing jig. This jig has four indexing positions, and note that the four clamps are provided with handles for sliding the clamp in and out over the work. This jig is used on a radial drill for drilling a large housing.

Angle Plates. In designing jigs and fixtures it is necessary at times to use angle plates. These are generally made out of cast iron, although there is a tendency today to use welded construction. In some plants a standard has been worked out on these angle plates, Fig. 44. In most plants a number of sizes shown in this illustration could be eliminated after an analysis was made of requirements; but it can be seen that there is an advantage in having a standard of this type, as it is only necessary to refer to the number of the angle plate required and it is available. Dimensions shown for these plates are the rough casting dimensions only, the finish required is generally indicated by the designer on the tool drawing.

Tool Holders. Plants using turret lathes, special turning machines, and crankshaft lathes, require tool holders to hold large tool bits. Therefore, in some plants standards have been worked out. Fig. 45 illustrates a forming tool holder for grooving crankshafts. Fig. 46 illustrates another type of standard tool holder for a ⅝″ square tool bit.

In designing tools for turret lathes, it is sometimes necessary to have tool holders for making a cut at right angles. Fig. 47 illustrates a standard tool holder for this type of job. Fig. 48 illustrates a standard tool holder for a ¾″ square tool bit. This type of tool holder is very simple and can be made readily in the shop's tool

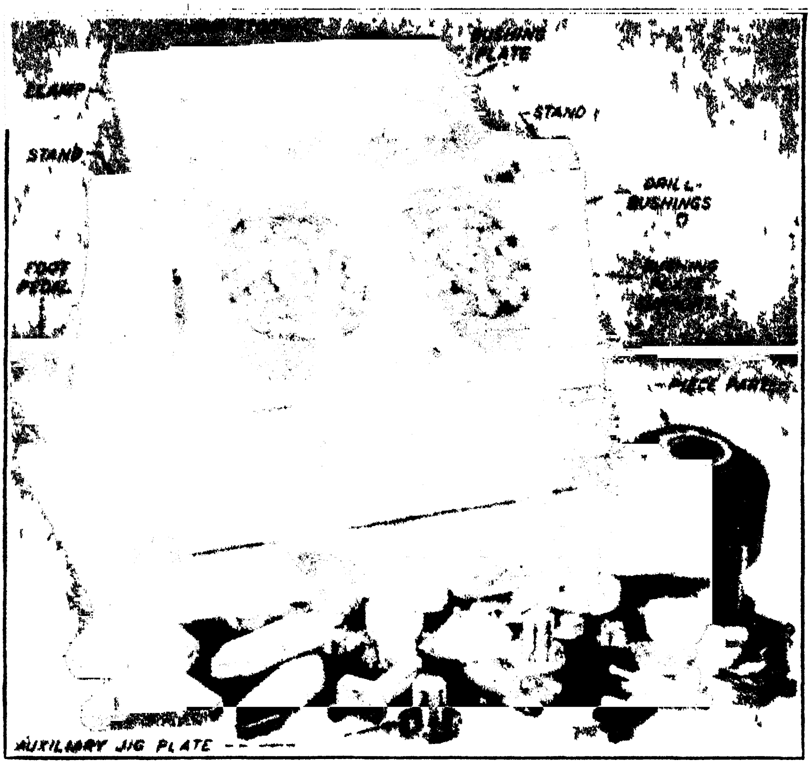


Fig 43A Turnover Jig Note the Stands

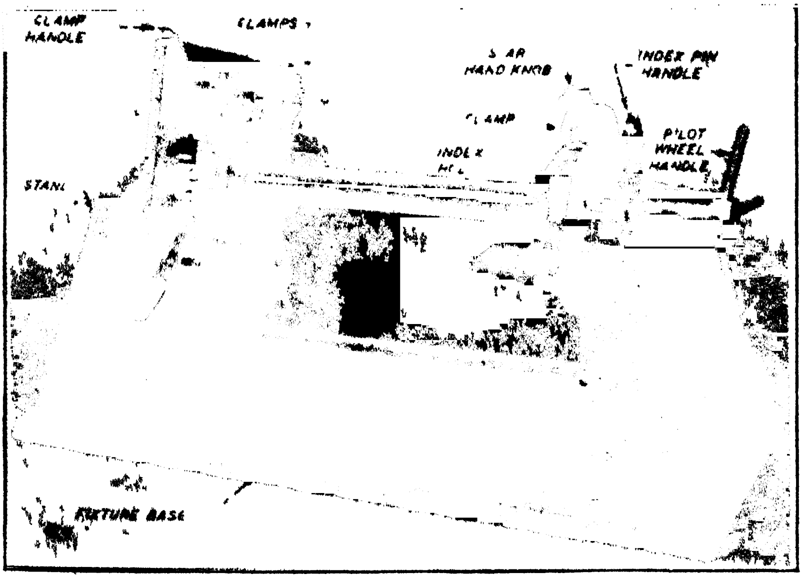


Fig 43B. Index Jig Supported by Stands

NO	A	B	C	D	E
1	4 3/4	4 3/4	3/4	3/4	12
2	5	5	1	1	8
3	5	5 1/4	3/4	3/4	4
4	5	8 1/2	1	1 5/8	4 1/2
5	5 3/4	5 3/4	3/4	3/4	12
6	5 3/4	14 1/2	1 3/8	7/8	6 1/2
7	6	6	3/4	3/4	16
8	6	7 1/4	1 1/4	3/4	4
9	6	8 1/2	1 1/4	1 5/8	4 1/2
10	6 1/2	7 1/4	7/8	1 5/8	4 3/4
11	6 3/4	6 3/4	3/4	3/4	12
12	6 3/4	8 1/2	1	1	5
13	7	6	1 1/2	1 1/2	6
14	7	7	1	1	6
15	7	11	1 1/8	1 1/8	10
16	7 1/2	6 3/4	1 3/8	1 3/8	13
17	7 3/4	11	1 3/4	1 3/4	10 1/2
18	8	10	1 1/4	1 1/4	8
19	9	7	1 1/8	1 1/8	7
20	10	8	7/8	7/8	8
21	10	10	1 1/4	1 1/8	10
22	12	7	1 1/4	1 1/4	6
23	12	8	1 1/2	1 1/4	10
24	13 1/2	13 1/2	1 3/8	1 3/8	12
25	16	14	1 3/8	1 3/8	14
26	10 1/2	9 1/2	1 1/2	1 1/2	12
27	4	3	1	1	14
28	11	22	1 1/2	1 1/2	16
29	15 1/4	6 1/4	1 5/8	1 7/8	12
30	17	11	1 1/4	1 1/4	7
31	7 1/4	6	2 1/4	1 1/2	5 1/2
32	9	7 3/4	3	1 3/4	7

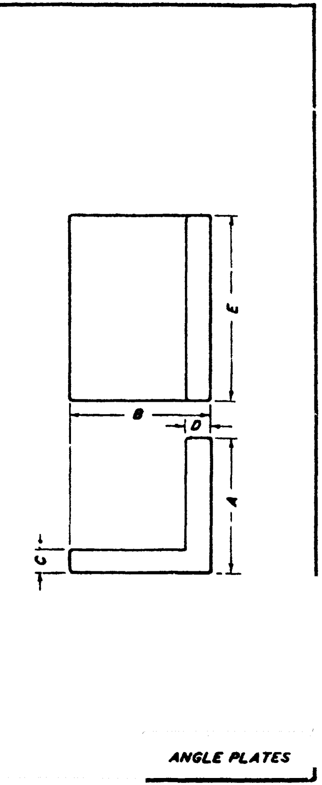


Fig. 44

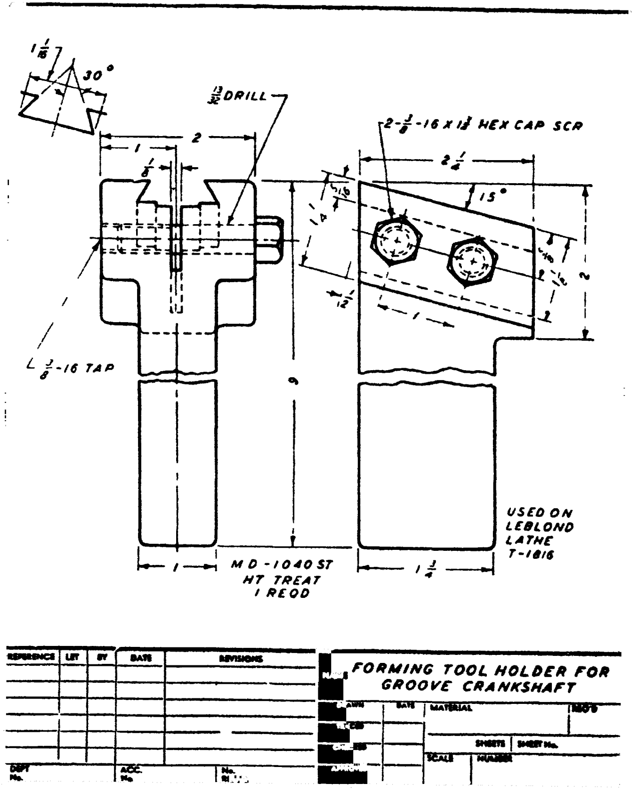


Fig 45

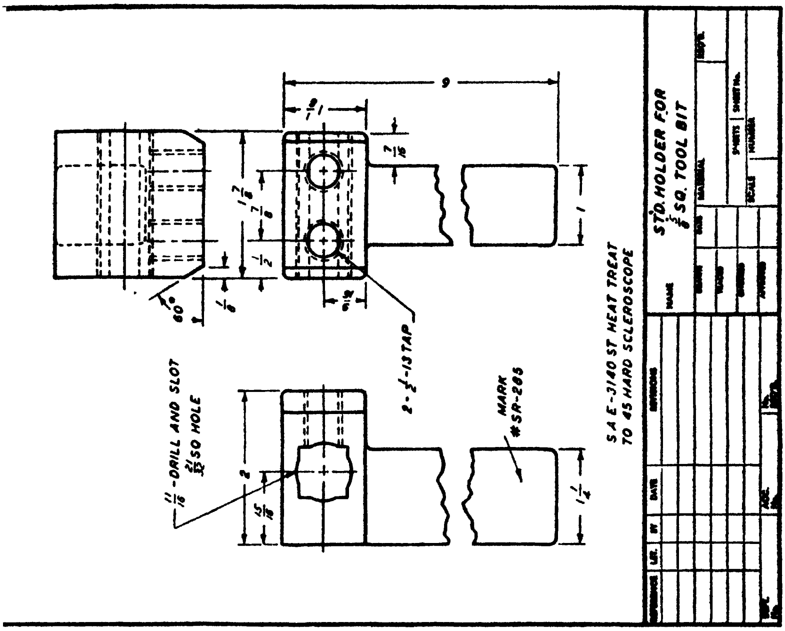

9
1 1/16
7/16
1 7/8
7/8
1/2
1/8
60°
9/16
1
2-1/2-13 TAP
11/16-DRILL AND SLOT
21/32 SQ HOLE
2
15/16
MARK
#SR-285
1 1/4
S A E-3140 ST HEAT TREAT
TO 45 HARD SCLEROSCOPE
STD. HOLDER FOR
5/8 SQ. TOOL BIT

Fig. 47

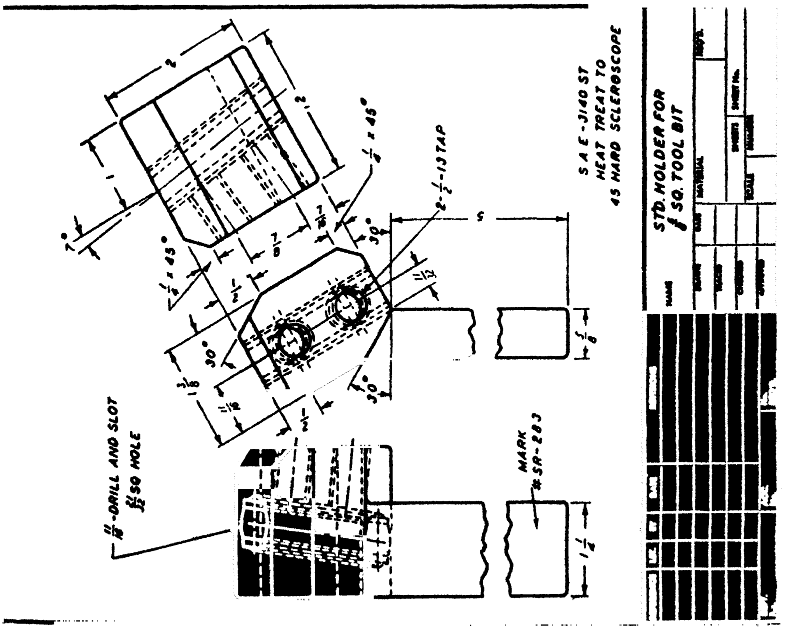

2
1 1/2
1
7°
1/8 x 45°
1/8 x 45°
7/8
30°
2-1/2-13 TAP
11/32
5
1 3/8
11/16
1/2
30°
5/8
11/16-DRILL AND SLOT
21/32 SQ HOLE
MARK
#SR-283
1 1/4
S A E-3140 ST
HEAT TREAT TO
45 HARD SCLEROSCOPE
STD. HOLDER FOR
SQ. TOOL BIT

Fig. 46

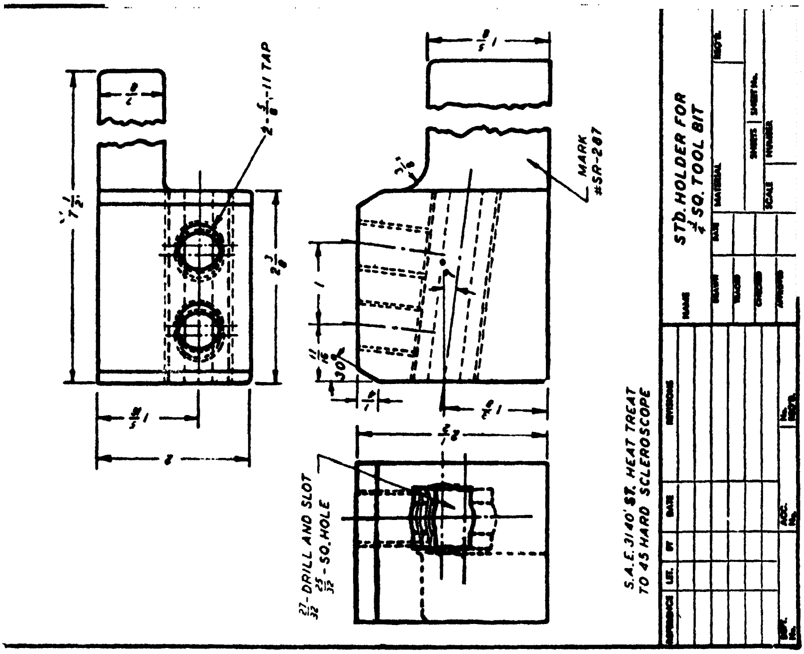

2-5/8-11 TAP
7 1/2
2 3/8
1 5/16
2
1 5/8
1
11/16
30°
1 1/2
2 1/2
MARK #SR-287
27/32-DRILL AND SLOT 25/32-SQ. HOLE
S.A.E. 3140 ST. HEAT TREAT TO 45 HARD SCLEROSCOPE
STD. HOLDER FOR 1/4 SQ. TOOL BIT
NAME
DRAWN
TRACED
CHECKED
APPROVED
MATERIAL
SCALE
SHEETS
SHEET No.
NUMBER
MFG'D.
REFERENCE
LTR.
BY
DATE
REVISIONS
ACC. No.
DEPT. No.
No. REQ'D.

Fig. 49

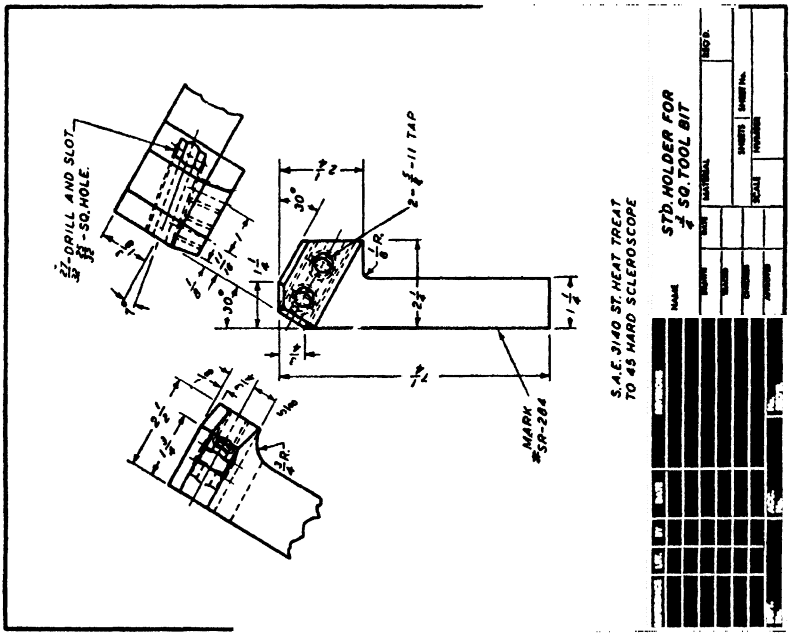

27/32-DRILL AND SLOT 25/32-SQ. HOLE.
2-5/8-11 TAP
2 1/2
30°
1/8 R.
1 1/4
2 1/4
1 1/4
30°
7 1/2
1/4
MARK #SR-284
2 1/2
1 3/8
3/8 R.
S.A.E. 3140 ST. HEAT TREAT TO 45 HARD SCLEROSCOPE
STD. HOLDER FOR 1/4 SQ. TOOL BIT
NAME
DRAWN
TRACED
CHECKED
APPROVED
MATERIAL
SCALE
SHEETS
SHEET No.
NUMBER
MFG'D.
REFERENCE
LTR.
BY
DATE
REVISIONS
ACC. No.
DEPT. No.
No. REQ'D.

Fig. 48

room. Fig. 49 illustrates an offset tool holder for a ¾″ square tool bit. A similar type of tool, but for a ⅝″ square tool bit, Fig. 50, illustrates the possibility of standardizing tools of this kind.

Fig. 51 shows a standard holder for a double grooving tool. This construction is somewhat similar to that used on spring collets, inasmuch as the holder itself is slotted and has sufficient spring so that the grooving tool is held securely in the holder when the screws are tightened. Fig. 52 is a holder for a single grooving tool. This tool is practically identical with the one shown on Fig. 51 except for the thickness.

Gages. High-speed production and interchangeable manufacturing naturally call for the wide use of gages. Today it is possible to buy a wide variety of standard gages from manufacturers who specialize on them. Certain plants require gages that are more readily adapted to their production or are cheaper than what can be purchased. Also there is the question of durability. By a process of evolution, certain types of gages have become standard in some plants. Since it would be impossible to show all these various types in a book of this kind, some of the most generally used standard gages are illustrated. In these drawings note that the various dimensions have been left blank. This is to permit the marking in of the dimensions needed for the job on which the gage is to be used. By having prints made in this manner, considerable designing time is saved.

Fig. 53 illustrates a depth gage and the gaging points are marked with a *G* on the line (this also denotes ground finish) and "go" and "no go" are shown in their respective locations. By having such a standard, a wide variety of jobs can be accommodated with a single design of this type. Fig. 54 shows a flat plug gage which can be made at small expense. They are generally used by the operators at the machines.

Fig. 55 illustrates a single plug gage. This type can also be used for checking the depth of a blind hole. Length gages, Fig. 56, are made of welded construction and the gaging points are tipped with Stellite for wear purposes. Certain dimensions are left blank so that this one design of gage can be used for a wide variety of jobs. Fig. 57 illustrates a double-end snap gage. This is a very simple form of gage and is generally given to the operator for use at a machine.

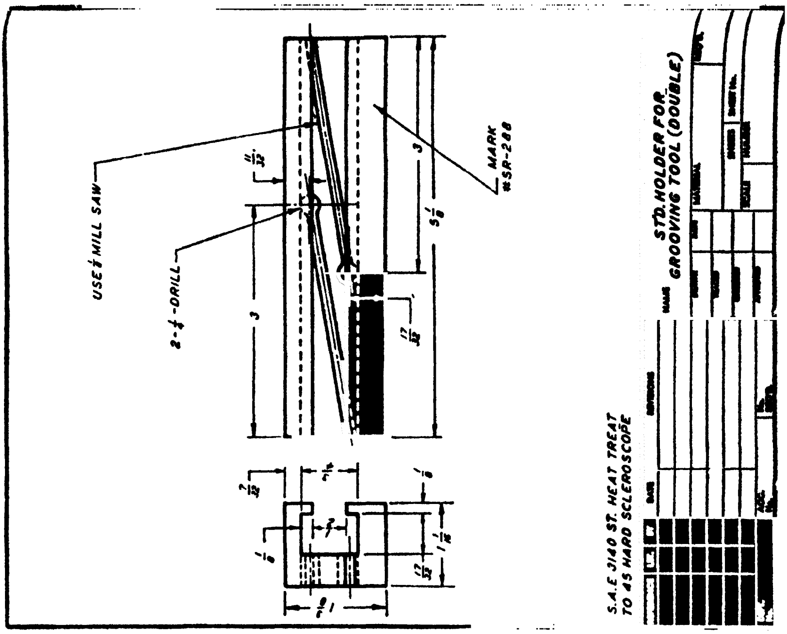

USE 1/8 MILL SAW
2-1/4-DRILL
MARK #SR-288
11/32
3
5 1/8
3
17/32
7/32
1/8
1/8
17/32
1 1/16
S.A.E 3140 ST. HEAT TREAT TO 45 HARD SCLEROSCOPE
STD. HOLDER FOR GROOVING TOOL (DOUBLE)

Fig. 51

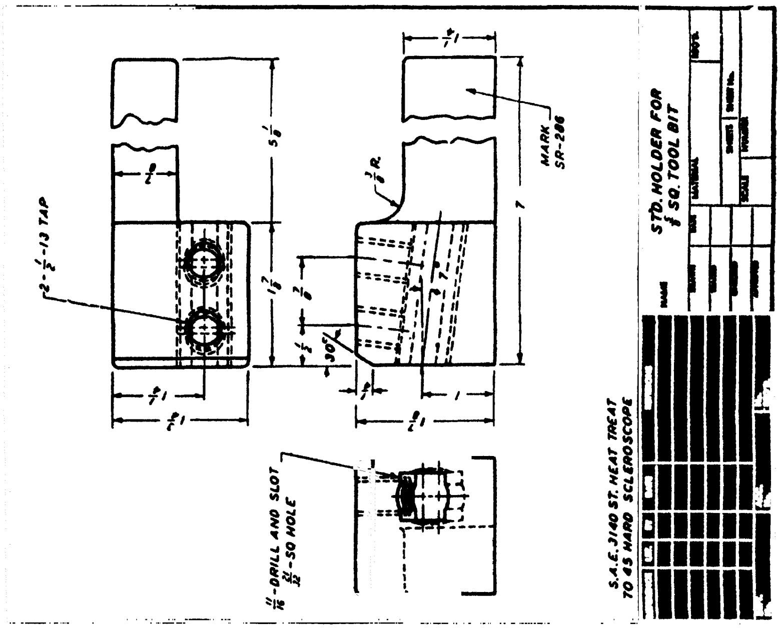

2-1/2-13 TAP
5 1/8
1 7/8
7/8
1/2
30°
3/8 R.
7
1
MARK SR-286
11/16-DRILL AND SLOT 21/32-SQ HOLE
S.A.E.3140 ST. HEAT TREAT TO 45 HARD SCLEROSCOPE
STD. HOLDER FOR 5/8 SQ. TOOL BIT

Fig. 50

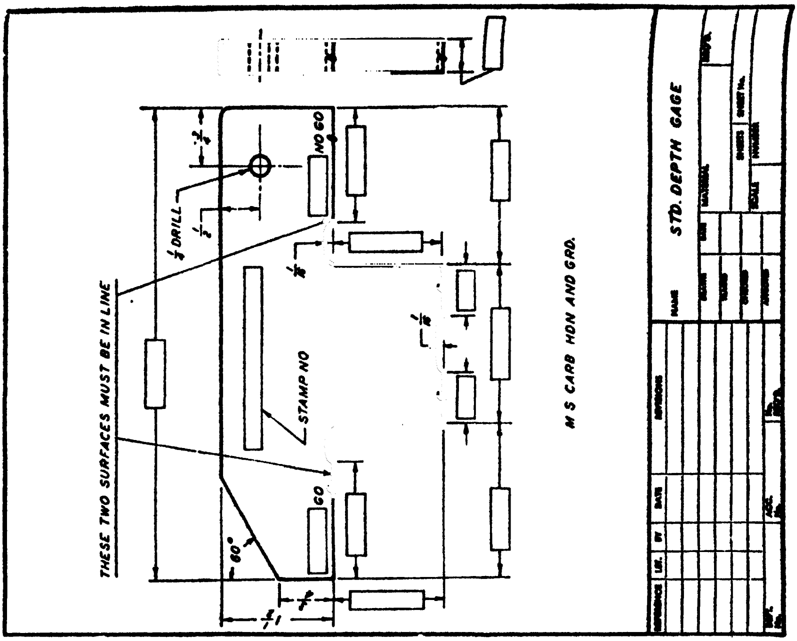

THESE TWO SURFACES MUST BE IN LINE
1/4 DRILL
1/2
1/4
NO GO
GO
STAMP NO
1/16
1/16
60°
1 1/8
1/8
M S CARB HDN AND GRD.
STD. DEPTH GAGE

Fig. 53

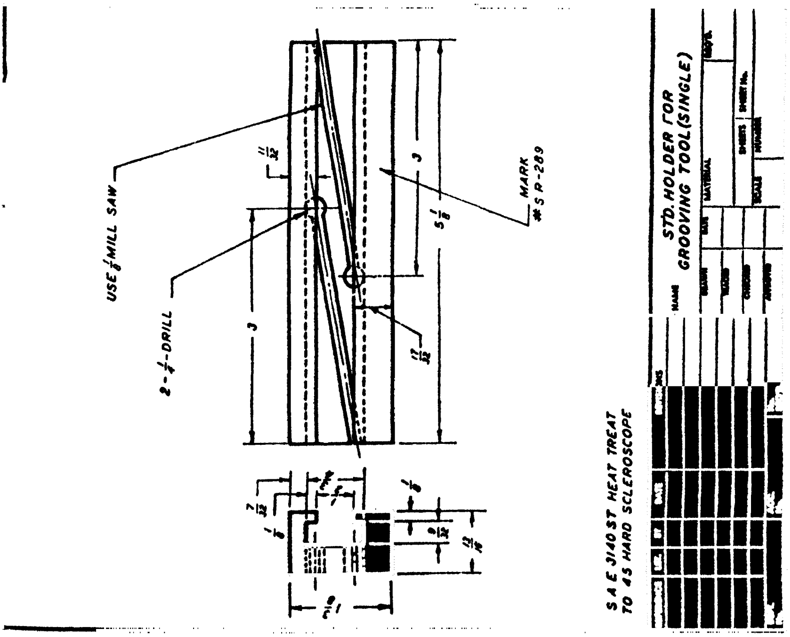
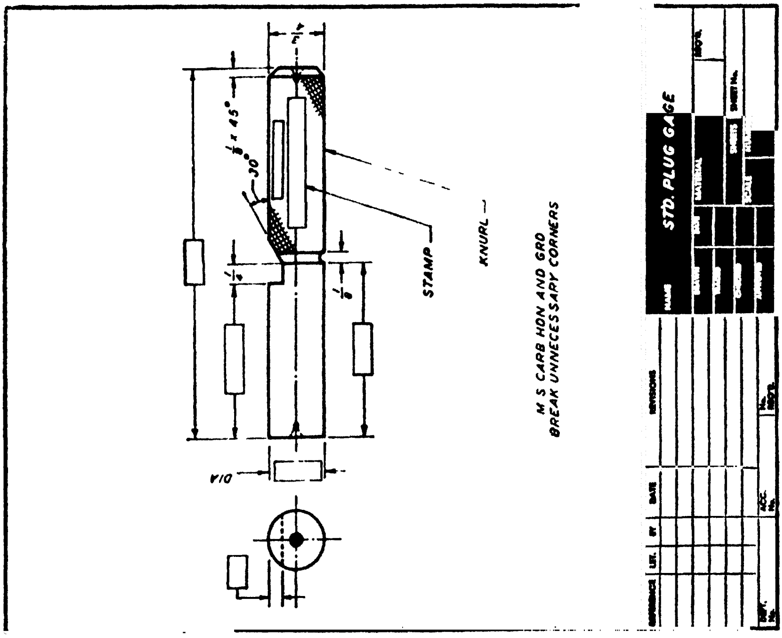
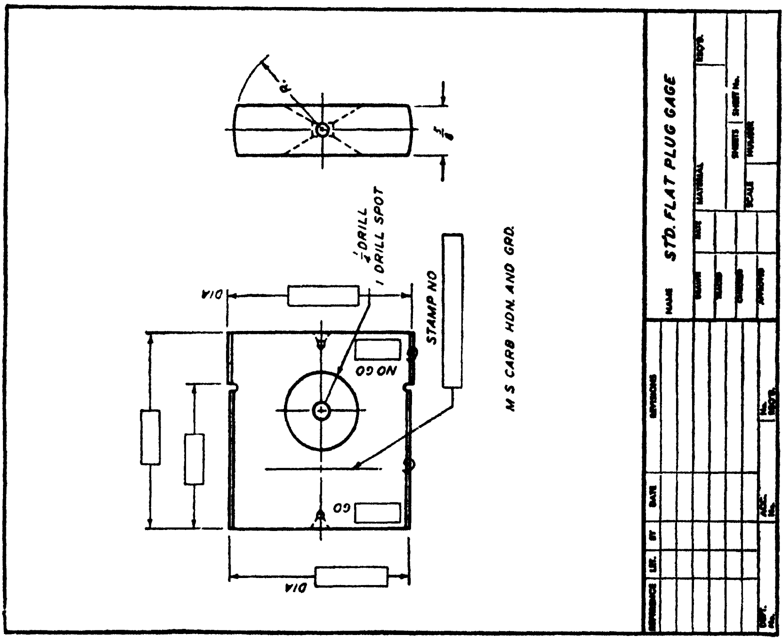

USE 1/8 MILL SAW
2-1/4-DRILL
11/32
3
5 1/8
MARK #SP-289
3
17/32
7/32
1/8
1/8
9/32
13/16
1 5/8
S A E 3140 ST HEAT TREAT
TO 45 HARD SCLEROSCOPE
STD. HOLDER FOR GROOVING TOOL (SINGLE)

Fig. 52



STD. PLUG GAGE
M S CARB HDN AND GRD
BREAK UNNECESSARY CORNERS
KNURL
STAMP
30°
1/8 x 45°
1/4
1/8
DIA
NAME
DESIGN
TRACED
CHECKED
APPROVED
SIZE
MATERIAL
SHEETS
SHEET No.
SCALE
NUMBER
REQ'D.
REFERENCE
LTR.
BY
DATE
REVISIONS
DEPT. No.
ACC. No.
No. REQ'D.

Fig. 55



STD. FLAT PLUG GAGE
M S CARB HDN. AND GRD.
STAMP NO
1/4 DRILL
1 DRILL SPOT
NO GO
GO
DIA
DIA
R.
NAME
DESIGN
TRACED
CHECKED
APPROVED
SIZE
MATERIAL
SHEETS
SHEET No.
SCALE
NUMBER
REQ'D.
REFERENCE
LTR.
BY
DATE
REVISIONS
DEPT. No.
ACC. No.
No. REQ'D.

Fig. 54

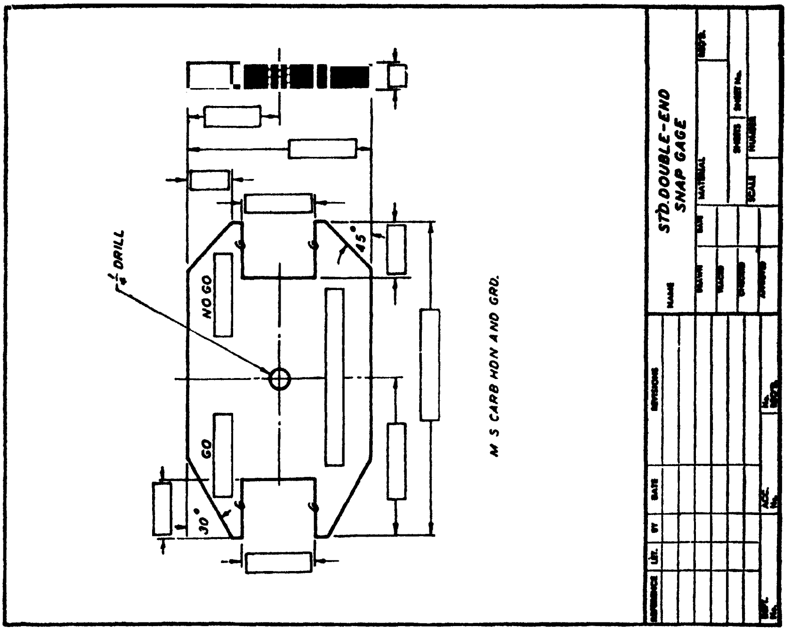

STD. DOUBLE-END SNAP GAGE
1/4 DRILL
NO GO
GO
45°
30°
M S CARB HDN AND GRD.
NAME
REVISIONS
MATERIAL
SCALE

Fig. 57

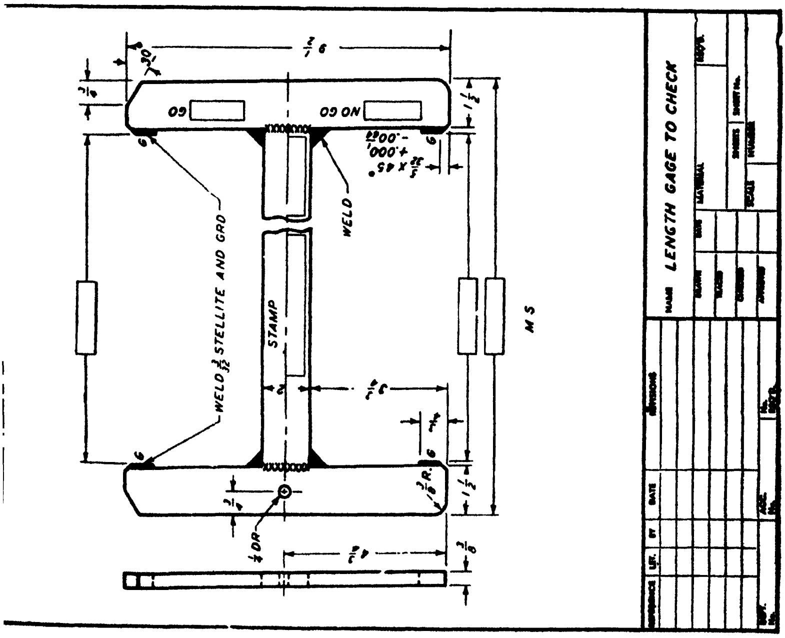

LENGTH GAGE TO CHECK
GO
NO GO
WELD
WELD 3/32 STELLITE AND GRD
STAMP
M S
1/4 DR
3/8 R.
1/32 X 45°
+.000, -.0004
30°
NAME
REVISIONS
MATERIAL
SCALE

Fig. 56

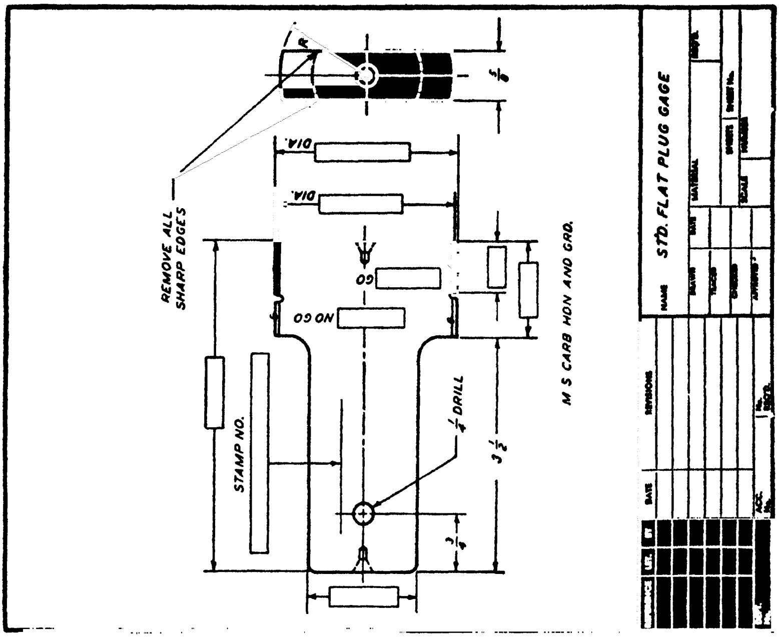

REMOVE ALL SHARP EDGES
R
DIA.
DIA.
GO
NO GO
STAMP NO.
1/4 DRILL
3 1/2
3/4
5/8
M S CARB HDN AND GRD.
STD. FLAT PLUG GAGE
NAME
DRAWN
TRACED
CHECKED
APPROVED
DATE
MATERIAL
REQ'D.
SCALE
SHEETS
SHEET No.
NUMBER
REVISIONS
DATE
No. REQ'D.
ACC. No.

Fig. 59

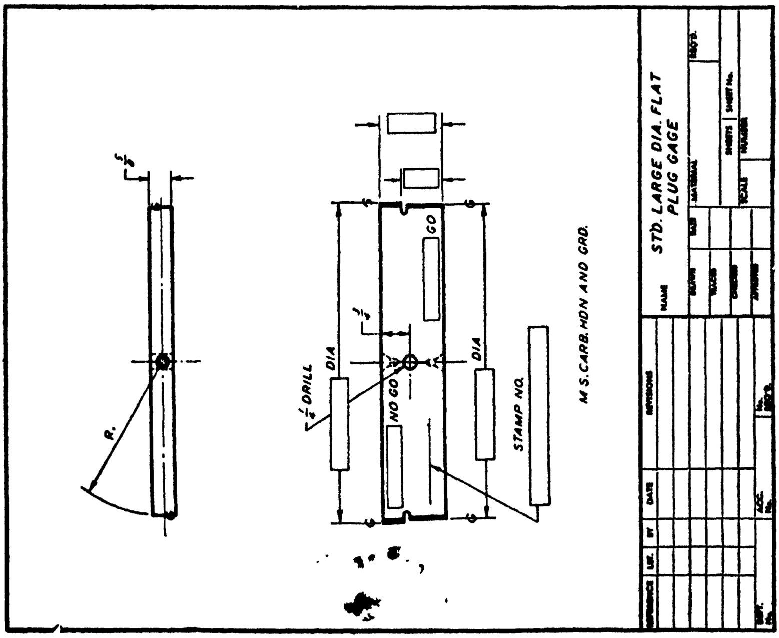

R.
5/8
1/4 DRILL
DIA
DIA
NO GO
GO
1/4
STAMP NO.
M S.CARB.HDN AND GRD.
STD. LARGE DIA. FLAT PLUG GAGE
NAME
DRAWN
TRACED
CHECKED
APPROVED
DATE
MATERIAL
REQ'D.
SCALE
SHEETS
SHEET No.
NUMBER
REVISIONS
DATE
BY
LTR.
REFERENCE
DEPT. No.
ACC. No.
No. REQ'D.

Fig. 58

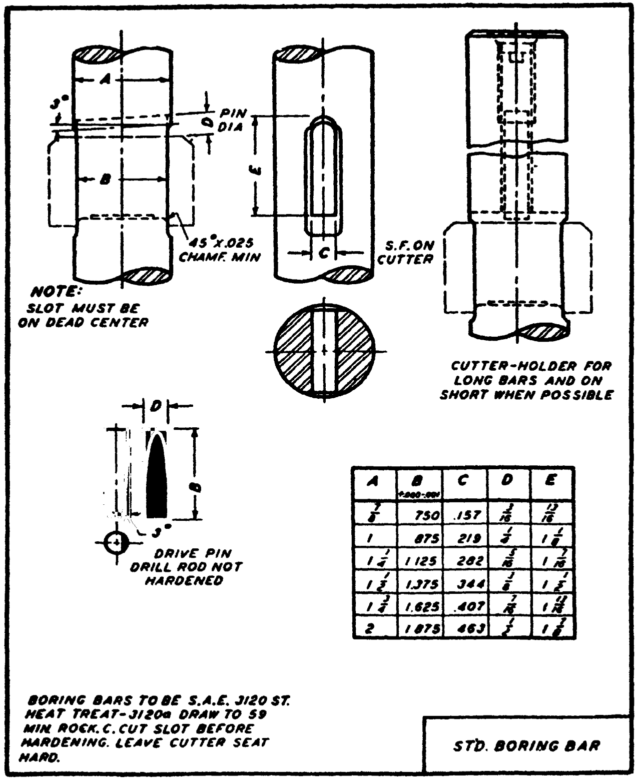
For plug gages of large diameter, a design similar to Fig. 58 is used. This type of gage is much cheaper than a solid round plug gage of similar dimensions. On jobs of smaller diameter, a flat plug gage with a handle, Fig. 59, is widely used. The design shown is also an inexpensive type of "go" and "no go" gage, with a step provided for indicating the proper dimensions. By leaving the dimensions blank on the tracing, a blueprint can be made and the required dimensions inserted in ink. In this manner designing of individual flat plug gages is avoided.

Boring Bars. These are extensively used in metal manufacturing, and a number of manufacturers specialize in items of this kind. However, certain plants have their own type of boring bar, particularly plants where the tool room is not kept busy making new tools.

Fig. 60 illustrates a standard type of boring bar that has been developed in a plant for special requirements. This type of bar is generally used where production is low and where a more expensive type of boring bar would not be required. The slot construction is very simple and two methods of holding the cutter in place are shown. These bars are not in general use, due to the fact that the cutters themselves are made out of solid high-speed steel, and unless there is a great variety of boring jobs it is evident that as soon as the cutter becomes worn it must be scrapped unless it can be ground down to a smaller size and used for smaller jobs. The design shown in Fig. 60 can be used on any length of bar, and as many slots as necessary can be put into the bar to suit the needs of the particular job. The design of locking device shown on the right-hand side of this drawing can be used to good advantage only on the end of the bar. The construction on the left-hand side of the drawing, showing the cutter inserted in the slot and held in place by a drive-pin or wedge, is used on the intersections of the bar.

Boring Bar Cutters. Fig. 61 illustrates various types of standard cutters used with the boring bar shown in Fig. 60. These cutters are all made of high-speed steel and the particular type of high-speed steel is specified on the tool drawing.

Punches and Dies. There are many plants that do a considerable amount of punch-press work in fabricating articles. In some of these plants it has been necessary to standardize on round and square punches. This works to advanta[illegible] a majority of jobs. Of course


A
B
3°
PIN DIA
D
45° X .025 CHAMF. MIN
NOTE: SLOT MUST BE ON DEAD CENTER
E
C
S.F. ON CUTTER
CUTTER-HOLDER FOR LONG BARS AND ON SHORT WHEN POSSIBLE
D
B
3°
DRIVE PIN DRILL ROD NOT HARDENED
BORING BARS TO BE S.A.E. 3120 ST. HEAT TREAT-3120a DRAW TO 59 MIN. ROCK. C. CUT SLOT BEFORE HARDENING. LEAVE CUTTER SEAT HARD.
STD. BORING BAR

A	B +.000-.001	C	D	E
7/8	750	.157	3/16	13/16
1	875	219	1/4	1 1/8
1 1/4	1 125	282	5/16	1 7/16
1 1/2	1.375	344	3/8	1 1/2
1 3/4	1.625	.407	7/16	1 11/16
2	1 875	463	1/2	1 7/8

Fig. 60

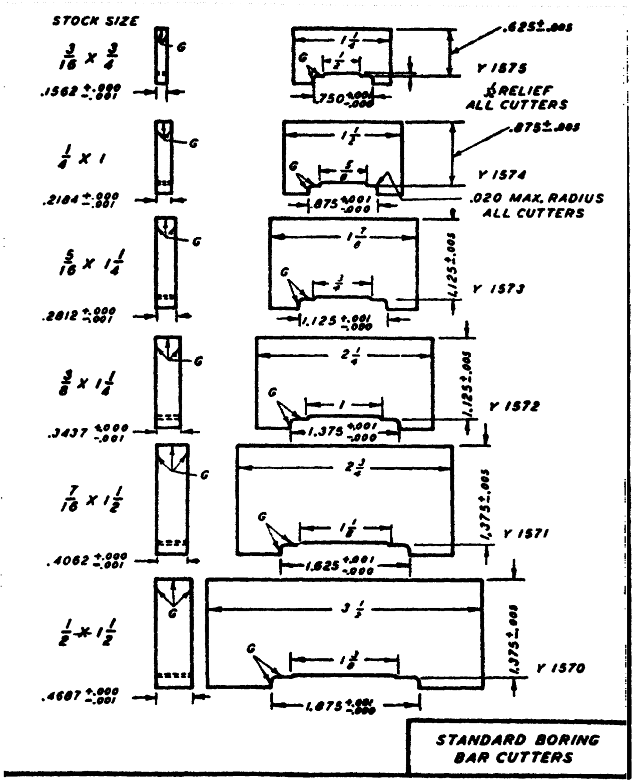
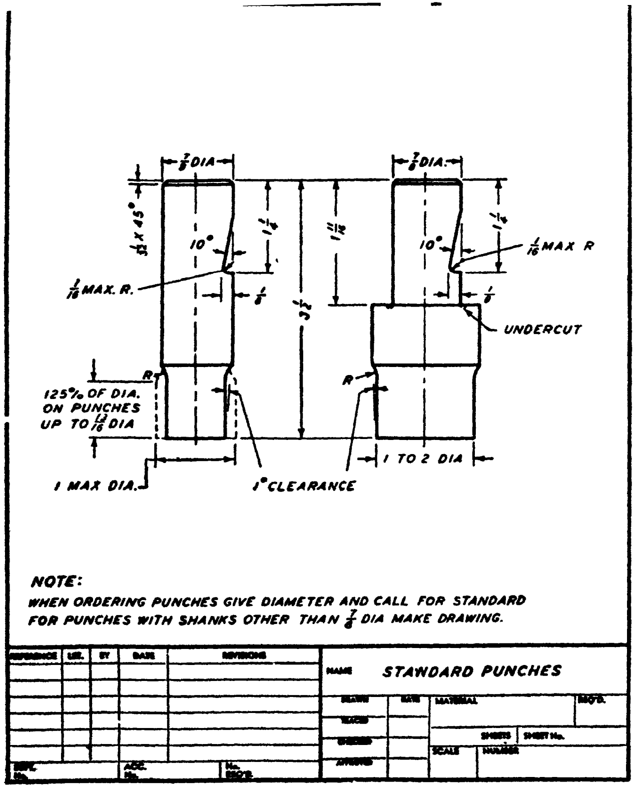
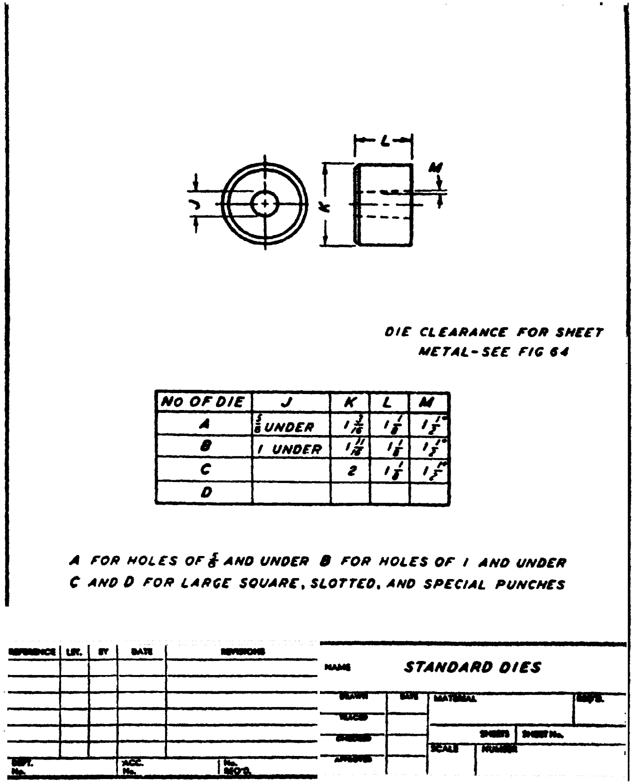


Fig. 62



NOTE:
WHEN ORDERING PUNCHES GIVE DIAMETER AND CALL FOR STANDARD
FOR PUNCHES WITH SHANKS OTHER THAN $\frac{7}{8}$ DIA MAKE DRAWING.

Fig. 62



DIE CLEARANCE FOR SHEET
METAL-SEE FIG 64

NO OF DIE	J	K	L	M
A	$\frac{5}{8}$ UNDER	$1\frac{3}{16}$	$1\frac{1}{8}$	$1\frac{1}{2}$°
B	1 UNDER	$1\frac{11}{16}$	$1\frac{1}{8}$	$1\frac{1}{2}$°
C		2	$1\frac{1}{8}$	$1\frac{1}{2}$°
D				

A FOR HOLES OF $\frac{5}{8}$ AND UNDER B FOR HOLES OF 1 AND UNDER
C AND D FOR LARGE SQUARE, SLOTTED, AND SPECIAL PUNCHES

Fig. 63

manufactured standard punches and dies are widely used in many plants. Fig. 62 illustrates a standard form of punch. This drawing shows the standard for punches up to 1" in diameter and another standard for punches from 1" to 2" in diameter. Adoption of a standard of this type makes it easy for the tool room to build up a supply of standard punches and saves considerable time in the tool designing department.

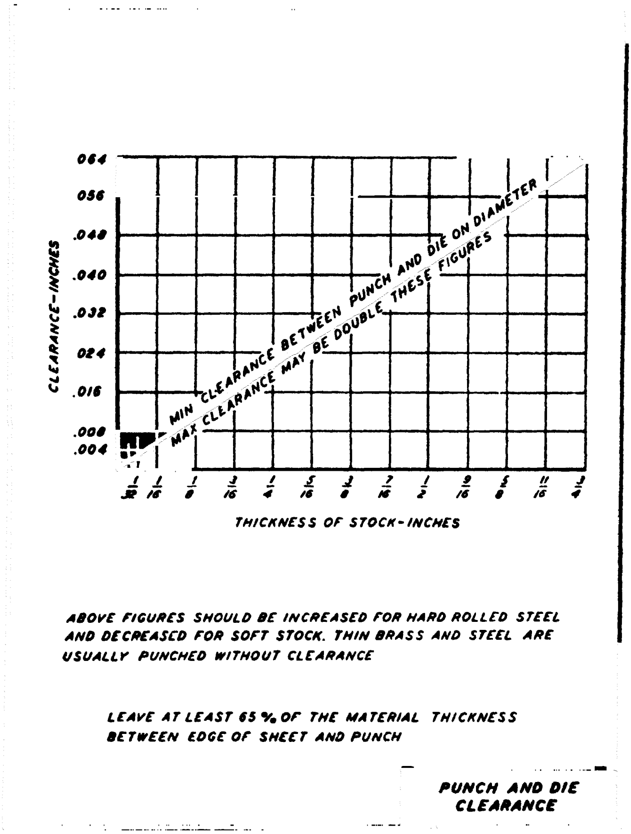
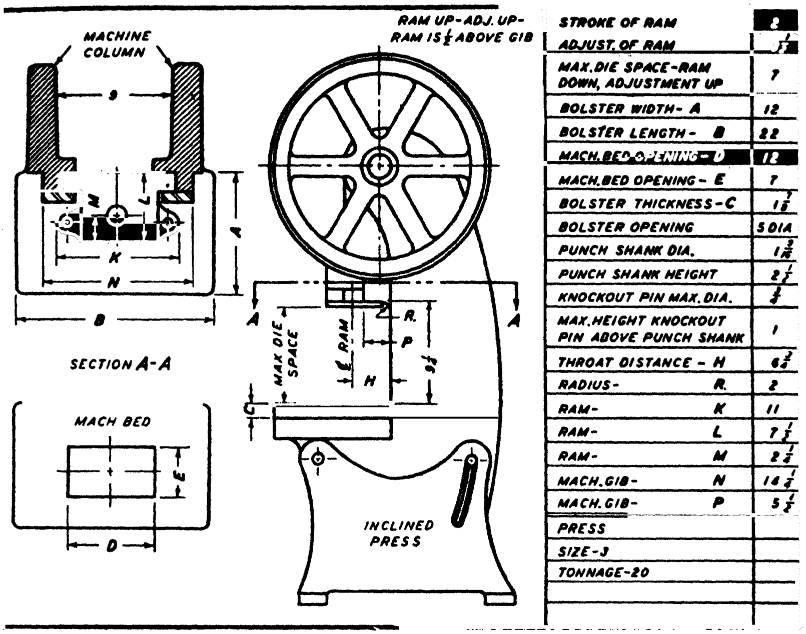


Fig. 64

Standard dies have also been worked out in some plants. These are commonly termed *button* dies. The design shown in Fig. 63 is the simplest possible form, and about the cheapest. On standard punches and dies, certain types of steel have become standard for *the kind of metal that is to be punched. This is also true of the heat* treatment on certain types of steel for punches and dies. Owing to the wide variation, it is impossible to present all this data.

In conjunction with the use of standard punches and dies a chart has been worked out, Fig. 64, showing the required clearance for various thicknesses of stock. These standards are not absolute, only approximate. They are the result of experience on punch operations in one plant. The amount of clearance between the punch and die sometimes has to be determined by a cut-and-try method. For the guidance of tool designers on die work, a standard data sheet, Fig. 65, is generally made up showing all necessary data to enable them to design dies properly. This chart gives the dimensions that are so necessary in designing dies for particular types of punch presses. Such sheets can be worked out to cover all the various types of presses available in the plant.



STROKE OF RAM	2
ADJUST. OF RAM	$1\frac{1}{2}$
MAX. DIE SPACE-RAM DOWN, ADJUSTMENT UP	7
BOLSTER WIDTH- A	12
BOLSTER LENGTH- B	22
MACH. BED OPENING- D	12
MACH. BED OPENING- E	7
BOLSTER THICKNESS-C	$1\frac{7}{8}$
BOLSTER OPENING	5 DIA
PUNCH SHANK DIA.	$1\frac{9}{16}$
PUNCH SHANK HEIGHT	$2\frac{1}{2}$
KNOCKOUT PIN MAX. DIA.	$\frac{3}{4}$
MAX. HEIGHT KNOCKOUT PIN ABOVE PUNCH SHANK	1
THROAT DISTANCE - H	$6\frac{3}{4}$
RADIUS- R.	2
RAM- K	11
RAM- L	$7\frac{1}{2}$
RAM- M	$2\frac{1}{4}$
MACH. GIB- N	$14\frac{1}{4}$
MACH. GIB- P	$5\frac{1}{2}$
PRESS	
SIZE-3	
TONNAGE-20	

Fig. 65. Data Sheet for Use on Die Work

Tool Bits. In some types of metal manufacturing, it is necessary to use a considerable number of cutting tools, particularly tool bits for use in engine lathes, shapers, planers, special automatic turning machines, etc. By constant efforts certain standards have been worked out on standard forms and sizes of tool bits, particularly

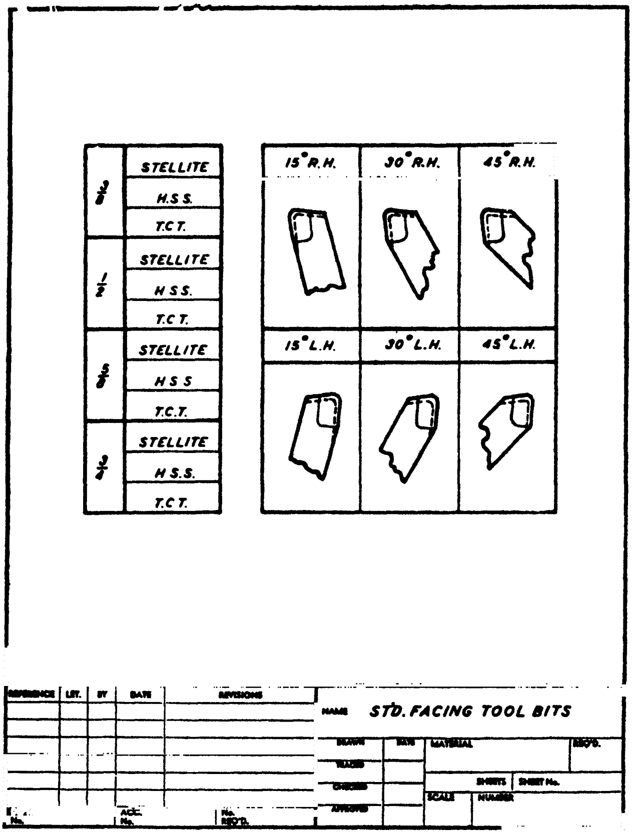


Fig. 66

since the introduction of Tungsten Carbide. Fig. 66 illustrates standard facing tool bits made of Stellite, of high-speed steel, and with Tungsten Carbide tips.

Fig. 67 illustrates standard turning tool bits made from Stellite, high-speed steel and with Tungsten Carbide tips. Fig. 68 shows standard boring tool bits. These also are made in Stellite, high-speed steel, and with Tungsten Carbide tips. Fig. 69 shows standard chamfering tool bits, made out of Stellite, high-speed steel, and

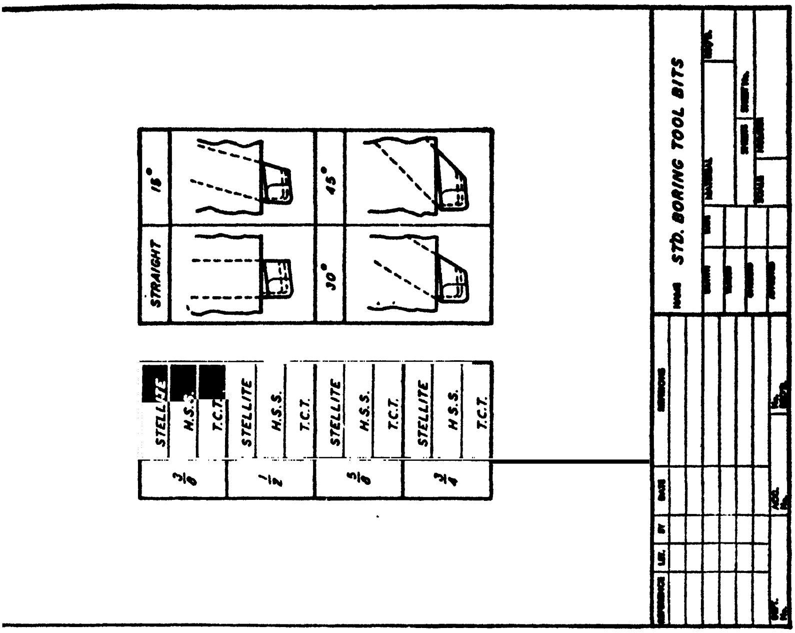

STD. BORING TOOL BITS
STRAIGHT
15°
30°
45°
3/8
1/2
5/8
3/4
STELLITE
H.S.S.
T.C.T.

Fig. 68

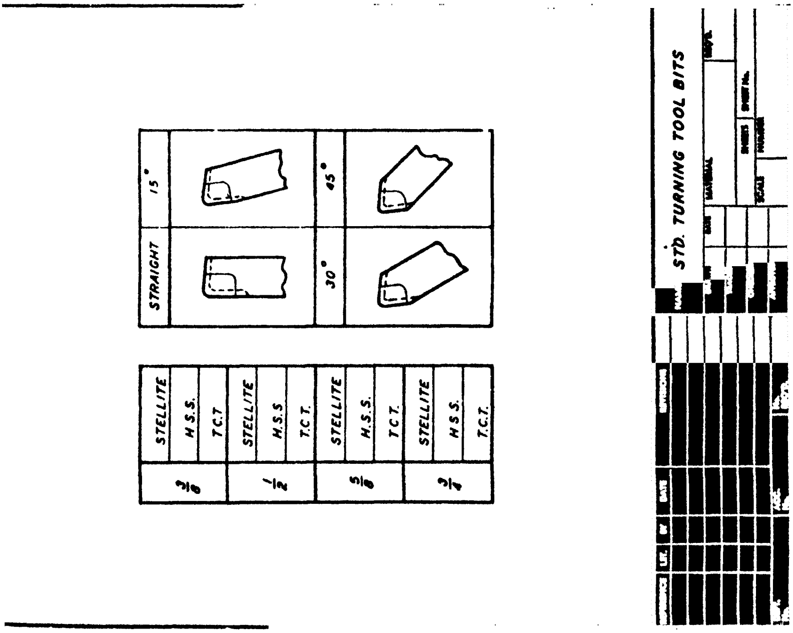
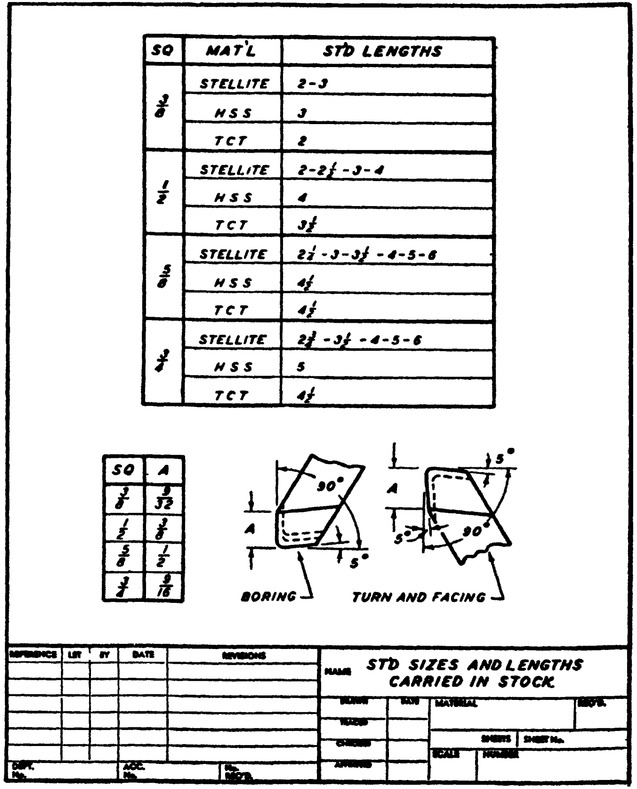

STD. TURNING TOOL BITS
STRAIGHT
15°
30°
45°
3/8
1/2
5/8
3/4
STELLITE
H.S.S.
T.C.T.

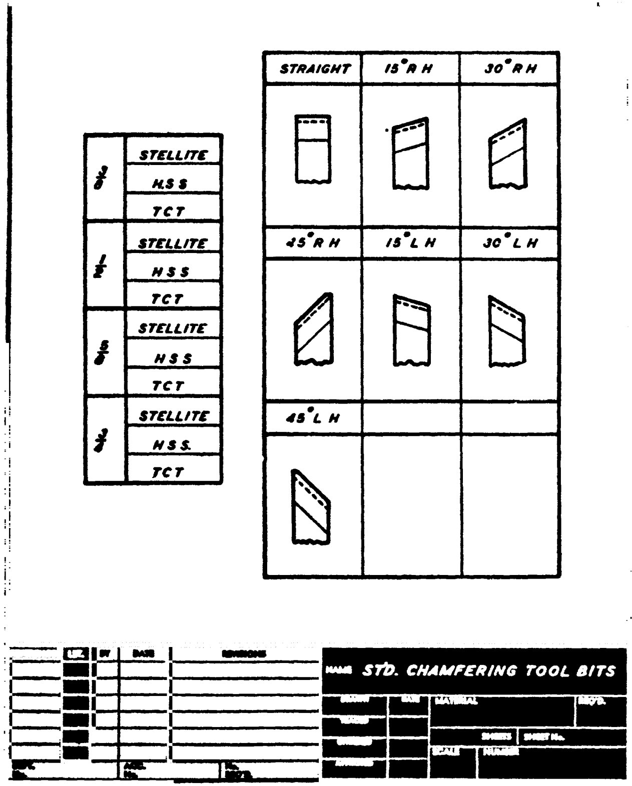
Fig. 67



SQ	MAT'L	STD LENGTHS
3/8	STELLITE	2-3
	HSS	3
	TCT	2
1/2	STELLITE	2-2½-3-4
	HSS	4
	TCT	3½
5/8	STELLITE	2½-3-3½-4-5-6
	HSS	4½
	TCT	4½
3/4	STELLITE	2¾-3½-4-5-6
	HSS	5
	TCT	4½

SQ	A
3/8	3/32
1/2	3/8
5/8	1/2
3/4	9/16

Fig. 70



3/8	STELLITE
	H.S.S
	TCT
1/2	STELLITE
	HSS
	TCT
5/8	STELLITE
	HSS
	TCT
3/4	STELLITE
	HSS.
	TCT

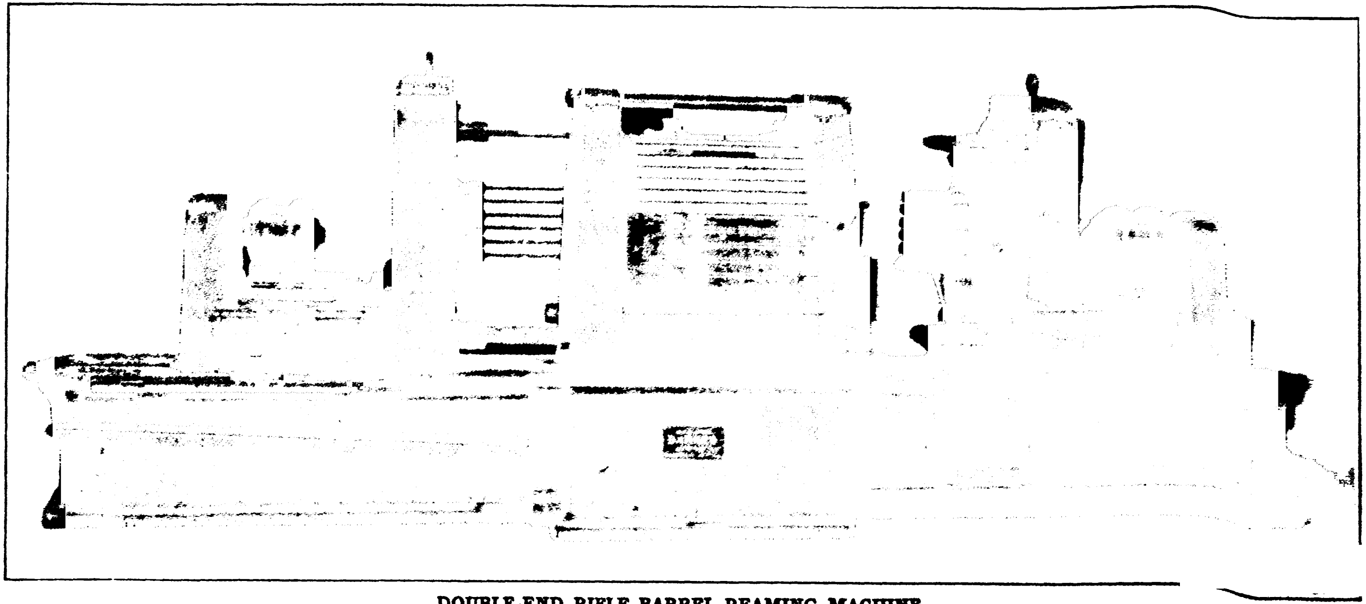
Fig. 69

Tungsten Carbide tips. The single dimension, such as ⅜", ½", ⅝", ¾", indicates that these tool bits are square. Fig. 70 is a chart worked out to show the various sizes and lengths that are regularly carried in stock in the plant. This enables the tool designer to pick out one of these standards in designing the necessary cutting tools and prevents excess inventory and the use of sizes that would not be readily obtainable.

The various standards described in the preceding pages are not complete, due to the fact that there are many standards that have been developed and used by certain industries that would not be used in other plants in the metal-working industries. Therefore, only standards that are, or can be, used by the majority of the metal-working plants are shown. Any attempt to cover the standards for the entire metal-working industry would occupy entirely too much space in a book of this kind.

QUIZ QUESTIONS

1. What is the advantage of having patterns and keeping quantities of standard castings of hand knobs on hand?
2. On what types of work are standard handwheels used?
3. When designing jig feet for small jigs, why is it considered good practice to use an insert type that is hardened and ground?
4. What is the general function of locator pins?
5. What is the function of the thread that is cut on the large end of a standard dowel pin?
6. What are some of the design and material features of each of the clamps illustrated by Figs. 26, 27, 28, and 29?
7. What are some of the design and material features of the various clamps illustrated in Figs. 31, 32, 33, 34, 35, 36, and 37?
8. What is the advantage of having standard designs for trunnion brackets or stands?
9. What are some of the special features of the stand illustrated in Fig. 43?
10. What is the special function of each of the standard tool holders illustrated in Figs. 48 and 51?
11. What type of work in manufacturing calls for a wide use of gages?
12. What is the special use of each of the gages illustrated in Figs. 53, 58, and 59?
13. On what type of work is the boring bar illustrated in Fig. 60 used?
14. What is the special value of a standard data sheet giving the clearance and other data for punch presses?



DOUBLE-END RIFLE BARREL REAMING MACHINE

Courtesy of W F & John Barnes Co , Rockford, Ill

COMMERCIAL STANDARDS

In the early days of the metal-working industry very few standard tools or items were available. Most plants made all required tools in their own shop or, in the event they lacked equipment to do so, the plant would send the job to some other shop that could make the tool or article required. Naturally, each plant had its own requirements to be satisfied and would furnish a sketch or a drawing giving the specifications of the article required. The result was that no two items of similar nature were alike. For example, bolts and nuts used by one plant in the manufacture of their product would not fit a similar article made by another company, notwithstanding the fact that the sizes of the bolts and nuts were supposed to be the same. Of course some manufacturers deliberately made their sizes different so that the customer would have to buy replacements from them. This was a mistaken policy, because the customer often would make the replacement part in his shop instead of purchasing it from the original manufacturer. This condition has improved due to the efforts of the engineering societies and the federal government, and in large part to the common sense and good judgment of the manufacturers themselves.

The demands of high-production industries for various standard items that could be obtained at reasonable prices has led to the development of many of these items. It also has led to the establishment of plants that have specialized in the manufacture of standard products that could be sold to the consumer plants. By specializing in the manufacture of certain items (for example, die sets), these can be made cheaper and better than the individual plants could make them in their own tool rooms.

Among some of the first commercial tools were milling cutters, twist drills, taps, dies, hacksaw blades, files, etc. When these items were first put on the market they varied greatly in size and type. However, due to standardization programs, the number of sizes, types, and specifications have been reduced, and most of these manufacturers have organized associations within their own groups.

All this has made it possible for the consumer companies to buy products at fair prices and at the same time have the assurance that these items will be within certain definite commercial limits.

Today it is possible to buy several ½″-13 thread taps from as many different manufacturers, and the holes that would be tapped with these several taps would all fit standard bolts made by other manufacturers. This would have been impossible a few years ago.

Drill Bushings. In tool-designing departments drill bushings are probably the articles of commercial manufacture most frequently used. In the old days each plant and individual tool designer had different ideas as to outside diameter, inside diameter, and length. In addition there were various designs of this item in general use. This was very expensive, as the drill bushing usually had to be made in the plant in very small quantities. Consequently when a drill bushing became worn and had to be replaced in the jig, it meant that the bushing would have to be pressed out of the jig plate and the dimensions of the drill bushing carefully checked so that a similar one could be made in the tool room. This would cause considerable delay in production because the drill jig would be out of service until a new bushing could be completed and fitted to the drill jig. With commercial bushings available today, a slip renewable bushing can be inserted in the drill jig in about one minute and the jig put into production immediately.

Most of these commercial bushings are furnished with an allowance for grinding on the outside diameter. This allowance is approximately .015″ so that in the event any error occurred in the boring of the jig plate it could be corrected by allowing for this error in grinding the drill bushings to the finished size. However, if the customer prefers, these bushings can be furnished ground to definite dimensions.

The commercial drill bushings available today are manufactured by several companies, and all are made to conform to specifications of the American Standards Association. These commercial drill bushings are made in six different types as follows:

Plain Renewable Bushings. These are used in liners for high-production operation and are quickly removable. They are furnished as standard in six lengths and are adapted to three types of locking methods in the jig plate.

Slip Renewable Knurled Head Bushings. These are used in liners for multiple operation in the same jig, and are furnished standard with two different locking methods. They are made in six lengths to suit the needs of the particular jig in which they are to be used.

Shoulder or Head Type Liner Bushings. These liner bushings are recommended for general use wherever possible. The shoulder design prevents the liners from being forced into the jig plate, particularly on cast-iron jigs. This type of liner is also best adapted for use with knurled head slip bushings.

Plain or Headless Type Liner Bushings. This type of liner bushing is generally used where it is necessary to have close distances and for flush mounting in jig plates without the necessity of surface machining or counterboring the top of the jig plate when made of cast iron.

Head Press Fit Bushings. When a comparatively small number of parts are to be produced in a jig and it is estimated that the replacement of bushings will not be necessary, this type of bushing is generally used. They are usually not removable and are intended to last for the life of the jig.

Headless Press Fit Bushings. These are used on limited production jobs, especially where center-to-center distance of adjacent bushings is so close that it would not permit room for the head press fit type of bushing; also where flush mounting of bushings in jig plates is desired. These bushings are used where it is only necessary to press the bushing directly into the jig plate. In using this type of bushing it is not necessary to machine the surface of the jig plate.

Clamp Locks. These are regularly manufactured in two types; that is, flat and round end clamps. They are used to lock the bushings securely into the liners. These clamps are generally used on jigs that are used for heavy drilling of steel and steel alloys where the chips would be stringy and might force the drill bushing out of the liner. The lock prevents the bushing from riding up the drill.

Lock Screws. These screws lock the bushing into the liner. They are generally used when the drilling operation is light and there will not be much pressure against the drill bushing due to chips.

The various types of drill and liner bushings, also clamps and lock screws, are shown in Fig. 1. These are the types that are most used in the designing of jigs. On certain jobs it might be necessary to design a special drill or reaming bushing in order to be able to accomplish certain definite purposes, but the tool designer should keep in mind that it is usually best to avoid the use of special bushings. In some instances it is possible to use standard bushings by making slight alterations (usually by grinding) in the tool room.

Slip Renewable Bushings. Fig. 2 illustrates a slip renewable bushing and gives a chart showing the various sizes in which these bushings can be obtained. This type of bushing is used where it is desirable to drill and ream a hole in a part without removing the part from the jig It is used with a liner bushing and if, for example, it is necessary to drill and ream a hole in a part to .500″, a slip renewable drill bushing of $\frac{31}{64}''$ inside diameter should be used. After drilling, the $\frac{31}{64}''$ diameter drill bushing would be removed from the liner, and a slip renewable reamer bushing with a .500″ dimension inside would be used for the reaming operation. The slip renewable bushing is also used for very accurate drilling where it would be necessary to change the bushing frequently, due to wear caused by the rotating action of the drill.

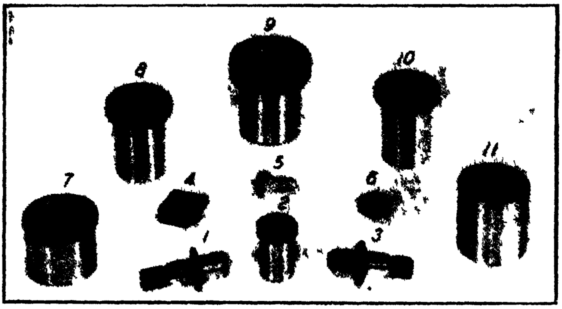
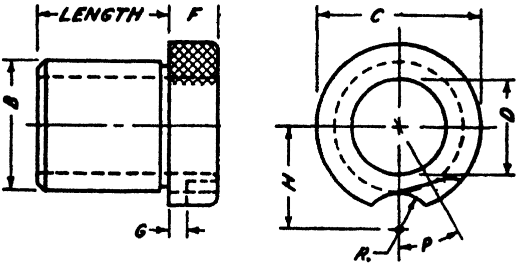


Fig. 1. Standard Drill Bushings. *1*, Locating Pin; *2*, Locating Retainer; *3*, Relieved Locating Pin; *4*, Flat Clamp, *5*, Lock Screw, *6*, Round End Clamp; *7*, Shoulder Liner; *8*, Plain Renewable Bushing, *9*, Slip Renewable Bushing, *10*, Head Press-Fit Bushing *11*, Headless Liner

Courtesy of Universal Engineering Co., Frankenmuth, Michigan

The various ways in which drill bushings are mounted in drill jigs are shown by Fig. 3. This illustration is self-explanatory. In addition to these methods, it is sometimes necessary to weld a handle on a shoulder-type bushing so as to permit its ready removal from

Slip Renewable Bushings—Dimensions, Inches



D Drill Size	B O. D. Body Grd. slipfit	C O. D. Head	F Head Thickness	Length	H Location of Screw	G Ledge	R Radius	P Angle	Lock Screw	Lock Clamp
No. 55 to 5/32	5/16	9/16	3/8	5/16 1/2 3/4 1	1/2	1/8	21/64	65°	No. 1	SC-1
9/64 to 11/32	1/2	13/16	7/16	5/16 1/2 3/4 1 1 3/8 1 3/4	5/8	1/8	21/64	65°		SC-11
9/32 to 17/32	3/4	1 1/16	7/16	1/2 3/4 1 1 3/8 1 3/4 2 1/8	3/4	1/8	21/64	50°		
15/32 to 25/32	1	1 7/16	1/2	1/2 3/4 1 1 3/8 1 3/4 2 1/8 2 1/2	59/64	3/16	21/64	35°	No. 2	SC-2
23/32 to 1 1/32	1 3/8	1 13/16	1/2	3/4 1 1 3/8 1 3/4 2 1/8 2 1/2	1 7/64	3/16	21/64	30°		SC-12
31/32 to 1 13/32	1 3/4	2 5/16	5/8	1 1 3/8 1 3/4 2 1/8 2 1/2 3	1 25/64	3/16	25/64	30°	No. 3	SC-3
1 11/32 to 1 25/32	2 1/4	2 13/16	5/8	1 1 3/8 1 3/4 2 1/8 2 1/2 3	1 41/64	3/16	25/64	25°		SC-13

Fig. 2

Courtesy of Universal Engineering Co., Frankenmuth, Michigan

the jig, particularly when it is dangerous for the operator to use his fingers because the drill press is running and the drills might cause personal injury.

There are many additional special adaptions of standard drill bushings that can be incorporated into drill jigs; for example, suppose that two holes must be drilled with very close center distances,

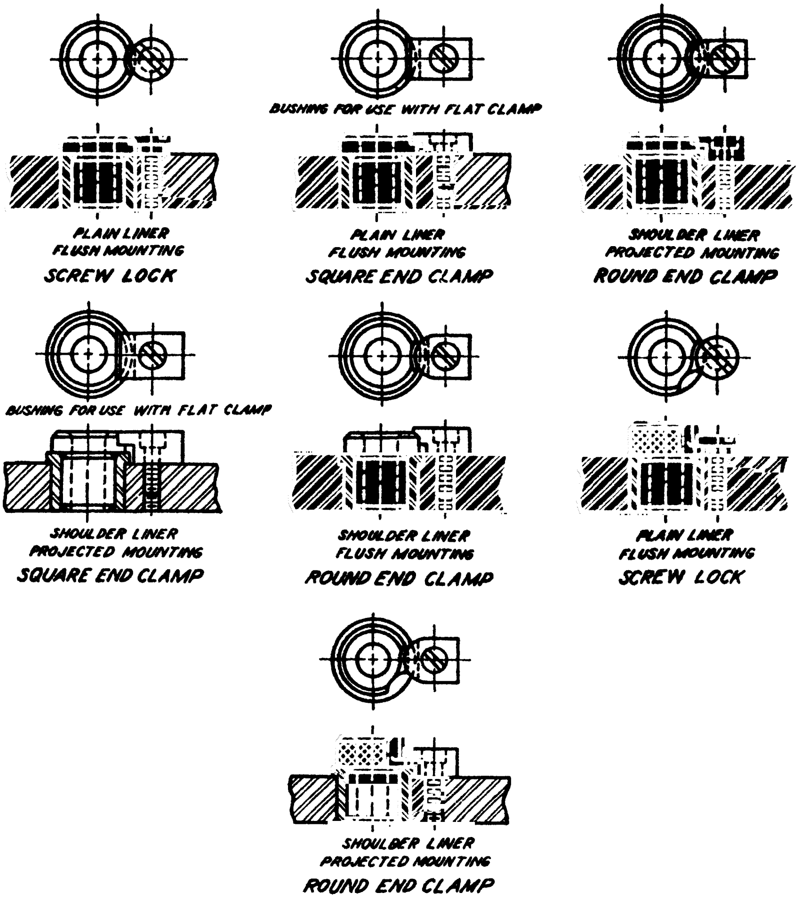


Fig. 3. Installation Layout of Universal Standard Drill Bushings
Courtesy of Universal Engineering Co., Frankenmuth, Michigan

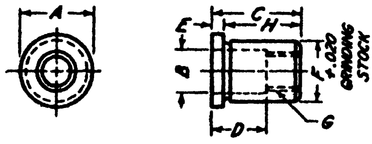
and upon checking the dimensions of the standard drill bushing it is apparent that the wall thickness of the bushings will not permit the insertion of a standard bushing in the jig plate so as to obtain the close dimensions required of the drilled holes. A condition of this kind can sometimes be overcome by grinding flutes on each of the two bushings. This permits the bushings to be inserted in a jig plate and thus a closer center distance can be obtained than could be had by using the bushings in their standard form.

Locating Pins and Retainers. In designing certain types of jigs and fixtures it is necessary to use locating pins and retainers. The pins are regularly furnished in two types, the round and relieved. They are used when it is necessary to locate a part in a jig and fixture in definite relation to certain previously machined surfaces or previously drilled holes. It is desirable to locate the part from a hole that has been drilled and reamed, so that there will be an accurate fit in the jig. The relieved pin is used in conjunction with the round type so as to permit a certain amount of play by the part, in the jig or fixture, particularly when the fit of the reamed hole is held very close.

Use of the locator retainer is somewhat similar to that of a drill bushing. In designing a jig that would use a locator retainer, the hole is accurately located and carefully bored. Then the outside diameter of the locator retainer is ground to fit this bored hole in the jig or fixture. The inside diameter of the locator retainer is ground to fit the shoulder of the locating pin. The locator retainer has a threaded section on the bottom so that the locating pin may be screwed into the threaded section, thus fastening it to the jig or fixture in the proper location. The threads on the locating pins and the locator retainer are ground to definite tolerances so that the fit will be very accurate and so as to provide a concentricity between the locator pin and the retainer.

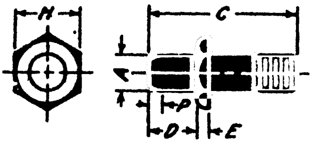
Fig. 4 illustrates two types of locating pins, retainers, and a chart showing the sizes that can be obtained readily. Therefore in designing jigs and fixtures all the tool designer needs to do is to insert in the specifications the diameter and style of locator pin or retainer required, and usually the name of the manufacturer is also put into the specification box on the tool drawing. Use of commercial items of this kind eliminates a considerable amount of designing time and effects a saving.

Rest Buttons. These are also commercially made and are illustrated in Fig. 4. They are designed to be used in conjunction with a locator retainer on jigs and fixtures where the design calls for a means of resting the part so as to obtain a proper support. In using the type illustrated in Fig. 4 it is necessary to drill and counterbore the particular section of the jig or fixture at the point where the rest button is going to be used. The surrounding surface can be left as is. These rest buttons are usually hardened to prevent wear.



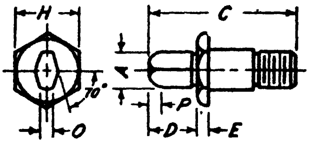
STYLE	A	B	C	D	E	F	G	H
1	$\frac{9}{16}$	.3125	$\frac{3}{4}$	$\frac{1}{2}$	$\frac{1}{32}$	$\frac{7}{16}$	$\frac{1}{4}$-24	$\frac{21}{32}$
2	$\frac{7}{8}$	.4375	1	$\frac{5}{8}$	$\frac{1}{8}$	$\frac{11}{16}$	$\frac{3}{8}$-24	$\frac{7}{8}$
3	1	.5625	$1\frac{5}{16}$	$\frac{3}{4}$	$\frac{5}{32}$	$\frac{13}{16}$	$\frac{1}{2}$-20	$1\frac{3}{32}$
4	$1\frac{3}{16}$	.8750	$1\frac{3}{4}$	$1\frac{1}{8}$	$\frac{1}{4}$	$1\frac{1}{4}$	$\frac{3}{4}$-16	$1\frac{1}{2}$

LOCATOR RETAINER



STYLE	A	C	D	E	H	P
C1	$\frac{3}{32}$-$\frac{5}{16}$	$1\frac{1}{4}$	$\frac{7}{16}$	$\frac{1}{32}$	$\frac{1}{2}$	$\frac{3}{32}$
C2	$\frac{5}{16}$-$\frac{7}{16}$	$1\frac{5}{8}$	$\frac{1}{2}$	$\frac{1}{8}$	$\frac{11}{16}$	$\frac{1}{8}$
C3	$\frac{7}{16}$-$\frac{5}{8}$	$2\frac{1}{8}$	$\frac{11}{16}$	$\frac{5}{32}$	$\frac{7}{8}$	$\frac{3}{16}$
C4	$\frac{5}{8}$-1	3	1	$\frac{1}{4}$	$1\frac{1}{4}$	$\frac{9}{32}$

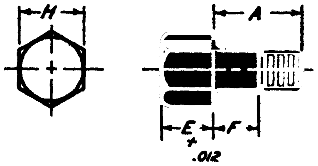
LOCATING REST PAD



STYLE	A	C	D	E	H	P	O
R1	$\frac{3}{32}$-$\frac{5}{16}$	$1\frac{1}{4}$	$\frac{7}{16}$	$\frac{3}{32}$	$\frac{1}{2}$	$\frac{3}{32}$	$\frac{1}{3}$
R2	$\frac{5}{16}$-$\frac{7}{16}$	$1\frac{5}{8}$	$\frac{1}{2}$	$\frac{1}{8}$	$\frac{11}{16}$	$\frac{1}{8}$	OF
R3	$\frac{7}{16}$-$\frac{5}{8}$	$2\frac{1}{8}$	$\frac{11}{16}$	$\frac{5}{32}$	$\frac{7}{8}$	$\frac{3}{16}$	A
R4	$\frac{5}{8}$-1	3	1	$\frac{1}{4}$	$1\frac{1}{4}$	$\frac{9}{32}$	DIM.

A-WILL BE GROUND TO SIZE GIVEN MINUS .0003 UNLESS OTHERWISE SPECIFIED. TOTAL LIMIT .0002

RELIEVED LOCATING PIN REST PAD



STYLE	A	E	F	H
B1	$\frac{3}{4}$	$\frac{3}{32}$-$\frac{3}{4}$	$\frac{3}{8}$	$\frac{1}{2}$
B2	1	$\frac{1}{8}$-$\frac{3}{4}$	$\frac{1}{2}$	$\frac{11}{16}$
B3	$1\frac{5}{16}$	$\frac{3}{16}$-$\frac{3}{4}$	$\frac{5}{8}$	$\frac{7}{8}$
B4	$1\frac{3}{4}$	$\frac{1}{4}$-$\frac{3}{4}$	1	$1\frac{1}{4}$

REST BUTTONS HAVE STOCK ON E DIM. FOR FINISHING

REST BUTTON

Fig. 4. Standardised Locating Pins and Retainers
Courtesy of Universal Engineering Co., Frankenmuth, Michigan

In the section on jigs and fixtures the use of the rest button is further described.

CLAMPS AND CLAMPING METHODS

The designing of jigs and fixtures calls for the use of clamps to hold the work securely while the machining operations are being performed. The use of the proper type of clamp applied at the correct point often determines whether the jig or fixture is properly designed for the job.

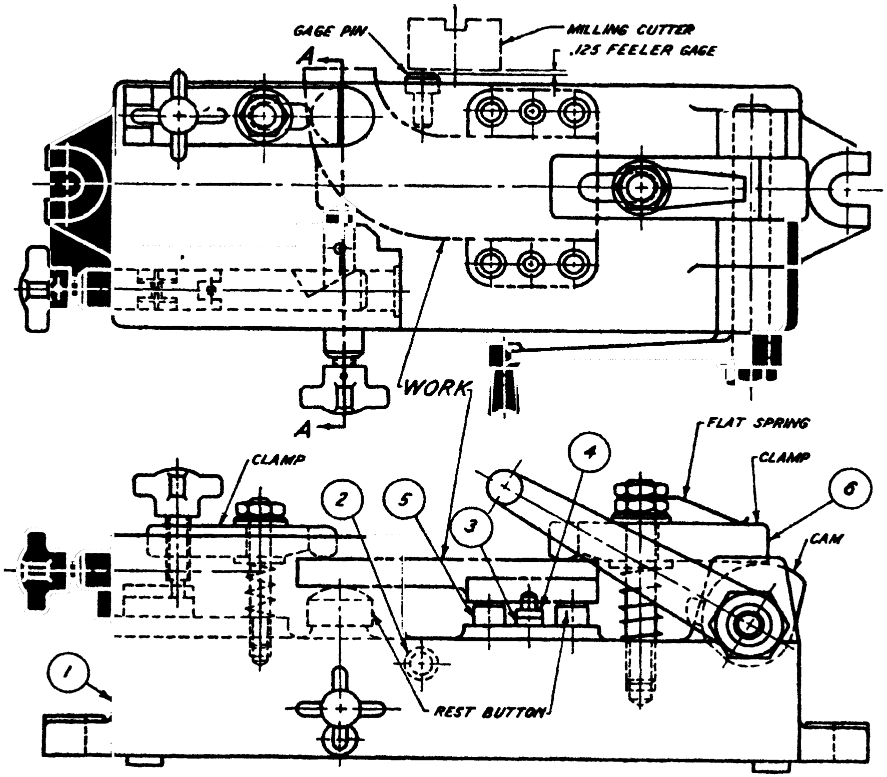
In the average plant where definite standards have not been adopted, the tool designer usually designs the clamps. This means that all types are to be found on jigs and fixtures. This condition has resulted in trouble and expense, because sometimes the clamps are too weak or are not properly designed for the work and allow the part to move in the jig or fixture.

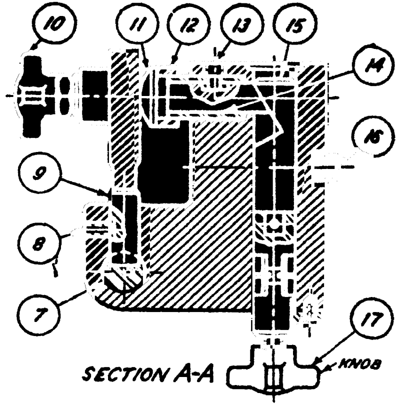
The selection of the right type and size of clamps is so important that the tool designer should give it careful consideration. He should make sure that the clamp has sufficient strength and that it is in the most accessible position.

A manufacturer, realizing the difficulties the average plant has had in obtaining the correct types of clamps for tools, has developed a number of standard designs in various sizes that are suitable for most of the jigs and fixtures used in plants. By using these standard clamps, considerable designing time can be saved, because the manufacturer of these clamps furnishes catalog sheets that can be used as templates under the tracing paper, thus permitting the tool designer to select the proper type and size of clamp and trace it on the tool drawing.

Standard Clamps. Fig. 5 illustrates the use of standard clamps and jig and fixture details. It will be noted that this milling fixture has seventeen details in the stock list; of these, eight are standard catalog parts, thus permitting a considerable saving in designing time, and cutting down the time required in the tool room to build a fixture of this type. The saving in cost must also be given consideration, as it is possible to purchase these standard parts cheaper than they can be built in the plant tool room.

Clamps with Springs. Fig. 6 shows a clamp that is widely used on various types of jigs and fixtures. It is furnished in three lengths. The clamp washers and clamp rest are hardened, the stud is alloy steel heat treated for toughness, and the hand knob is made of steel. There is a coil spring underneath the clamp so that the clamp springs away from the work when the hand knob is loosened, permitting the rapid removal of the work from the jig or fixture. In addition, a small pin is inserted in the heel of the clamp so that it can be pushed forward on to the work or pulled back as the case may be.





No. Req.	Det. No.	Name	Stock
1	1	Patt. K-216-1	C.I.
*1	2	Standard	RB-500
2	3	Locator	....
2	4	Bushing	....
*4	5	Standard	RB-375
*1	6	Standard	J-45
1	7	1 D.x4	M.S.
1	8	⅜-16x¾	Screw
1	9	⅞ D.x2	M.S.
*1	10	Standard	C-40
1	11	1½ D.x3	M.S.
1	12	1½ D.x⅝	M.S.
1	13	⅜-16x1	Screw
1	14	1¼ D.x2	M.S.
1	15	1 D.x3½	M.S.
*2	16	Standard	K-687
*2	17	Standard	JL-275

In this table, *D* = diam., *M.S.* = mach. st.

Fig. 5. Clamps Shown on Milling Fixture with Standard Parts

Courtesy of Siewek Tool Company, Ferndale, Michigan

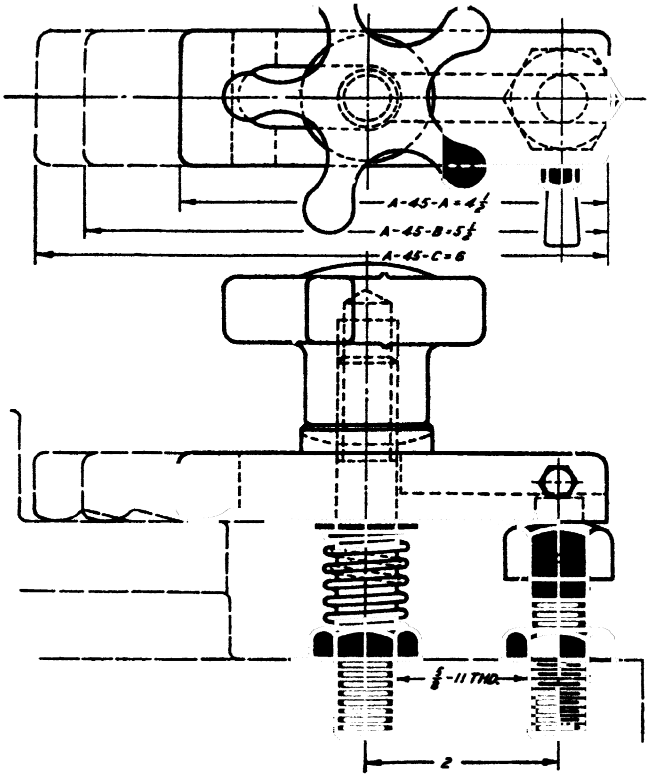


Fig. 6. Clamp with Spring

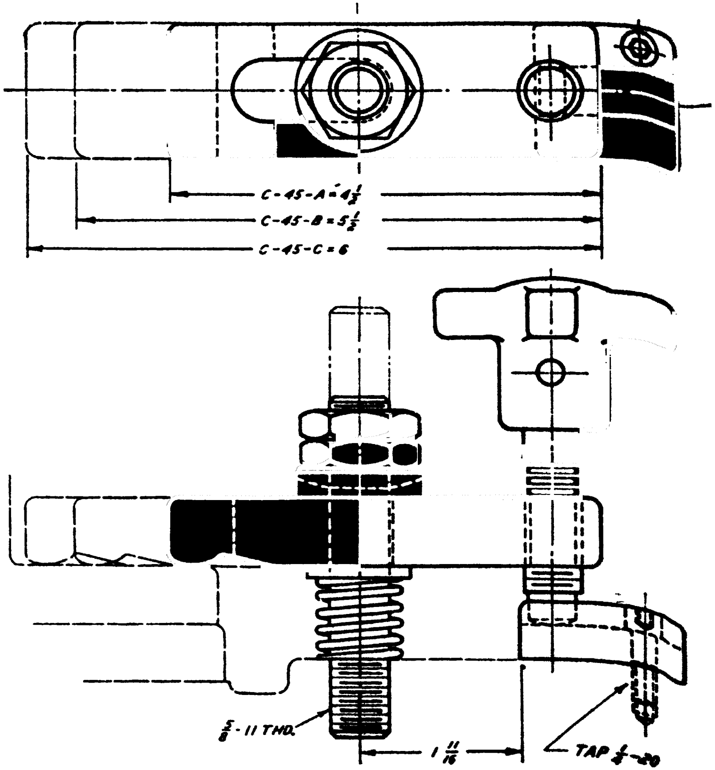


Fig. 7. Clamp with Lock Nuts and with Hand Knob in the Heel

Figs. 6 and 7, Courtesy of Sieuck Tool Company, Ferndale, Michigan

Spherical washers are used between the knob and the clamp itself, so that the pressure of the clamp can be equalized on the work in the jig or fixture. These clamps are furnished in sizes to suit the needs of most of the jigs and fixtures commonly used.

The clamp shown in Fig. 7 is somewhat similar to that shown in Fig. 6, but it is capable of a wider range of adjustment than is provided in the previously described clamp. The clamp rest is a different type, being mounted on the base of the jig or fixture. The clamp itself is fastened to the fixture by means of a stud that has a spherical washer with two lock nuts. This permits proper adjustment for height for the work being done in the jig or fixture. The hand knob is put into the heel of the clamp, and the knob is used for sliding the clamp in or out over the work. Considerable pressure can be applied with a clamp of this type, due to the location of the fulcrum point. The clamp washers and clamp rest are hardened, the studs are alloy steel heat treated, and the hand knob is made of steel.

Note that the size of clamp shown is furnished in three standard lengths. The figure shows only one ¼"-20 tapped hole for locating the clamp rest in position on the jig or fixture, but usually two holes and two hollow-head set screws are used. These clamps are furnished in a range of sizes suitable for most jobs.

Clamps with Cam Handles. Where fast operation is required of a clamp, a cam clamp, Fig. 8, is generally used. This clamp is somewhat similar to that described in Fig. 6, but it is operated by means of a cam handle. This permits rapid clamping, since it is necessary only to push the clamp itself in over the work and pull down the cam handle to clamp the work securely in position. These are furnished in various sizes, but due to their cost they are most generally used on high-production jobs where the floor-to-floor time is important.

Clamps Operated by Roller Type Cams. On some types of jigs and fixtures it is necessary to have a means of operating a clamp on the outer portion or side of a jig so as to prevent interference with the cutting tools. When this condition is encountered, a cam clamp similar to Fig. 9 is used. This cam clamp is controlled by a roller type cam that is operated by a lever located on the side of the jig or fixture. This clamping method is also used where

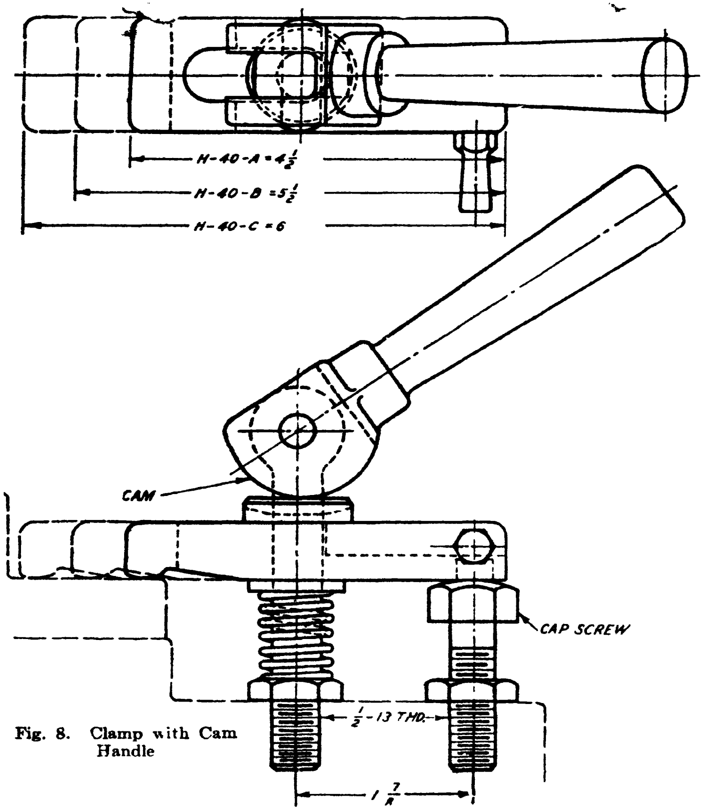


Fig. 8. Clamp with Cam Handle

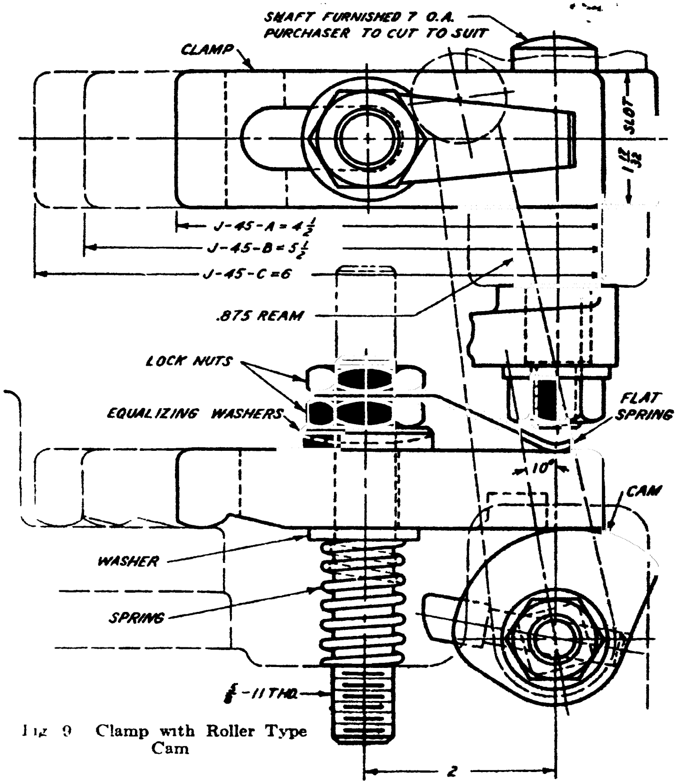


Fig. 9 Clamp with Roller Type Cam

Figs. 8 and 9, Courtesy of Steuek Tool Company, Ferndale, Michigan production runs are high and the saving in floor-to-floor time would affect the ultimate costs. This type of clamp is furnished in various sizes and lengths to suit the needs of a great many jobs.

Jack Locks. To position work in a jig and fixture prior to clamping, it is often necessary to use a jack lock. This item has now been standardized and can be purchased in various sizes. Fig. 10 illustrates a detail and a typical application in a fixture.

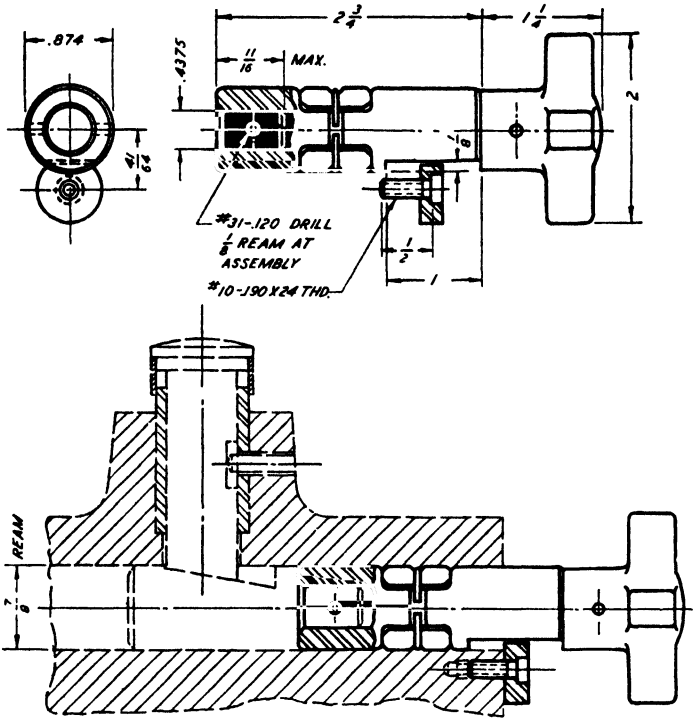


Fig. 10. Jack Lock and Typical Application
Courtesy of Siewek Tool Company, Ferndale, Michigan

Clamps of Minimum Height. On a great many milling fixtures it is necessary to provide clamps that can be held to a minimum height and still get considerable pressure to hold the work securely. When a condition of this kind is encountered, clamps similar to Fig. 11 are used. This clamp is fastened to the stud by means of an acorn nut which can be tightened by a wrench. These clamps are furnished in various sizes to suit the needs of most jobs.

Swinging Clamps. On small types of work, particularly castings such as cover plates and other thin-wall castings that are irregular in form, it is necessary to use swinging clamps that can readily be moved out of the way to permit the removal of work from the jig or fixture. On jobs of this kind, clamps similar to Fig. 12 are often used. These can be mounted in a jig or fixture so that they may be swung quickly to one side to permit rapid removal of the work from the jig or fixture.

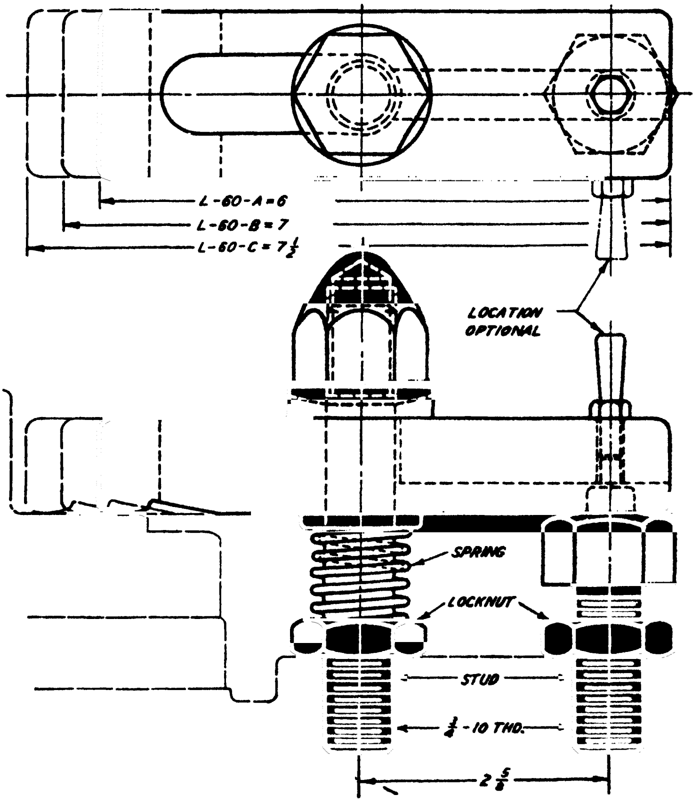


Fig. 11. Clamp of Minimum Height

Courtesy of Siewek Tool Company, Ferndale, Michigan

Another type of swinging clamp which is used on large milling fixtures, or sometimes in the planer, is shown by Fig. 13. This clamp is designed so that it can be used in places where other types of

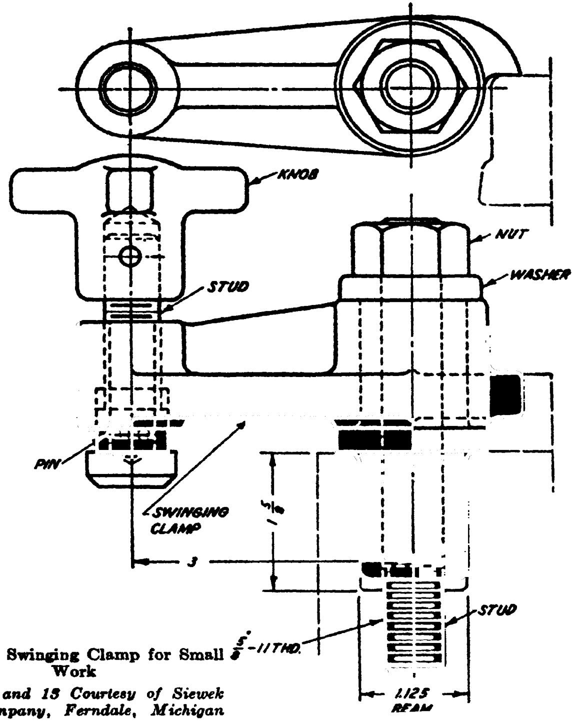


Fig. 12. Swinging Clamp for Small Work

Figs. 12 and 13 Courtesy of Siewek Tool Company, Ferndale, Michigan

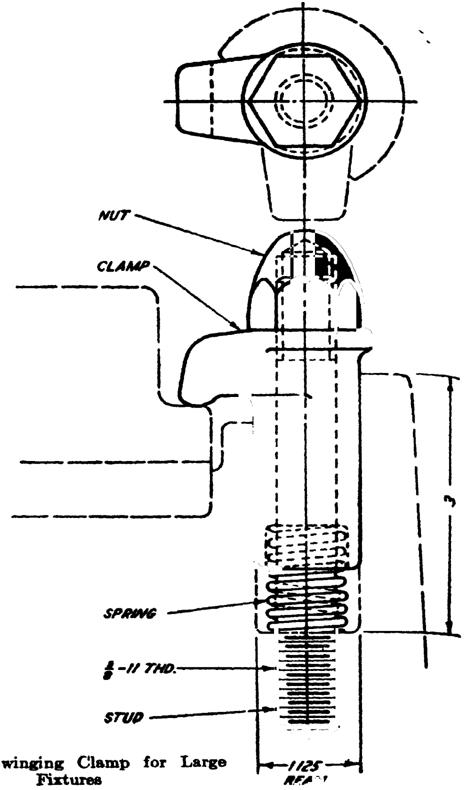
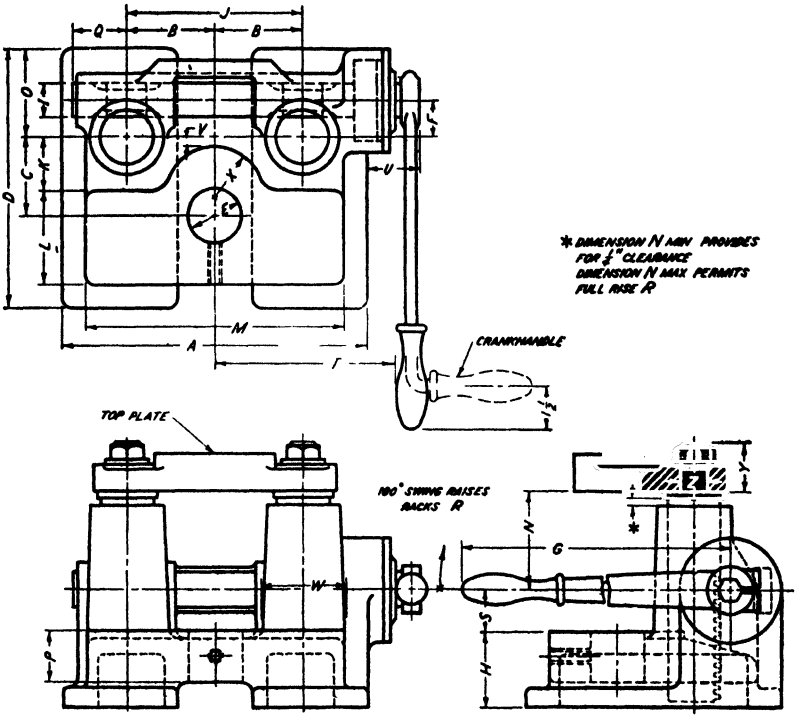


Fig. Swinging Clamp for Large Fixtures

clamps would cause interference. It is mounted in a stud and there is a spring under the clamp itself. It is fastened by means of an acorn nut which is tightened with a wrench. When the work is to be removed, the acorn nut is loosened and the clamp section is swung to one side so as to permit ready removal of the work.

STANDARDIZED DRILL JIGS


J
Q
B
B
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T
* DIMENSION N MIN PROVIDES FOR 1/4" CLEARANCE DIMENSION N MAX PERMITS FULL RISE R
CRANKHANDLE
1 1/2
TOP PLATE
180° SWING RAISES RACKS R
W
N
*
G
Y
Z
S
H

Fig 14. Rack and Pinion Type Jig
Courtesy of The Cleveland Universal Jig Co., Cleveland, Ohio

For a number of years the design of jigs varied according to the individual plants. Sometimes several different types of jigs would be used on identical parts. Some of these designs were good, but most of them were totally unsuited to the job. Usually the most complicated jigs were the ones that caused the most trouble. The need for standardization on drill jigs had been apparent in industry for many years, but up to some twenty years ago nothing very much was done along this line.

Jig Dimensions, Inches

Dim.	Jig Sizes						
	A3	A3-2	A4	A4-2	A5	A5-2	A7
A	6 5/8	6 5/8	8 3/4	8 3/4	11 1/4	11 1/4	16
B	1.875	1.875	2.500	2.500	3.252	3.252	5.000
C	1.000	1 to 2 1/4	2.000	2 to 3	2.000	2 to 3 1/2	Std. 3.500 3 1/2 to 4 1/2
D	5 7/8	5 7/8	8	8	9 5/8	9 5/8	11 5/8
E	1.000	1.000	1.500	1.500	2.000	2.000	2.750
F	.750	.750	1.150	1.150	1.400	1.400	1.625
G	8	8	10	10	12	12	15
H	1 3/4	1 3/4	2 1/2	2 1/2	2 7/8	2 7/8	4 1/4
I	3/4	3/4	1 1/4	1 1/4	1 1/4	1 1/4	1 1/2
J	3.750	3.750	5.000	5.000	6.504	6.504	10.000
K	1 1/4	1 1/4	1 5/8	1 5/8	2	2	2 1/2
L	2	2	2 1/2	2 1/2	3 3/8	3 3/8	4
M	5 3/8	5 3/8	7 1/4	7 1/4	9 1/2	9 1/2	13 3/4
N Min.	3 1/4	3 1/4	4 1/4	4 1/4	5	5	6 1/4
N Max.	4	4	5	5	6	6	8
O	2	2	3 1/8	3 1/8	3 3/8	3 3/8	4
P	1 1/4	1 1/4	1 5/8	1 5/8	1 7/8	1 7/8	2 3/4
Q	1 5/32	1 5/32	1 7/16	1 7/16	2	2	2 3/8
R	1	1	1 5/8	1 5/8	1 5/8	1 5/8	2
S	1/2	1/2	3/4	3/4	1	1	1
T	4 1/8	4 1/8	5 3/16	5 3/16	6 5/8	6 5/8	8 9/16
U	1 3/4	1 3/4	1 3/4	1 3/4	2	2	1 9/16
V	1/8	1/8	1/2	1/2	1/8	1/8	1
W	1 5/8	1 5/8	2 1/4	2 1/4	3	3	3 3/4
X	7/8	7/8	1 1/2	1 1/2	1 7/8	1 7/8	2 1/2
Y	1 1/8	1 1/8	1 11/16	1 11/16	1 11/16	1 11/16	2 7/8
Z	.6245	.6245	.9995	.9995	.9995	.9995	1.3745
Size of Lock	No. 10	No. 10	No. 20	No. 20	No. 20	No. 20	No. 30

Fig. 15

Courtesy of The Cleveland Universal Jig Co., Cleveland, Ohio

Rack and Pinion Type Jigs. Due to increasing demands, standardized jigs were developed and manufactured. Fig. 14 illustrates one of these, a rack and pinion type. The top plate is raised and lowered by means of racks milled on the post, and the top plate is locked by means of a toggle lock. This type of jig is manufactured in a number of sizes that were developed by studying the needs of the majority of metal-working plants. Any number of parts of approximately the same over-all size can be machined in this same jig by changing the top plates and the lower adapter which is mounted in the base of the jig. By using this type of jig considerable designing time is saved, and a large saving is effected by making the jig itself in the tool room.

An outstanding advantage of this type of jig is the saving in loading and unloading time, provided the jig is properly tooled; that is, if the adapters are so designed that the part can be put in and taken out of the jig with a minimum loss of time. On the average job that would be suitable for a jig of this type, the loading and unloading time is approximately five seconds.

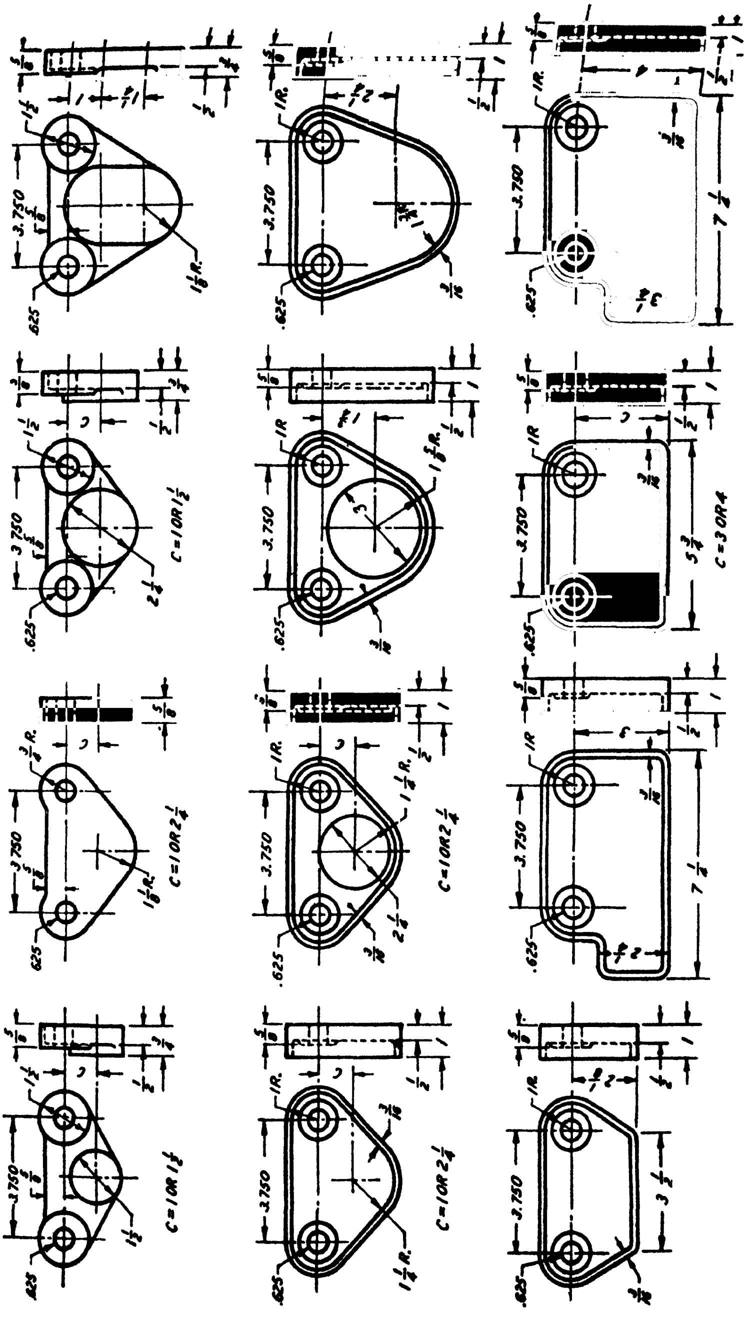


Fig. 16. Top Plates for Jigs Ready for Assembly with Rack Holes Bored and Bottom and Bosses Finished

Courtesy of The Cleveland Universal Jig Co., Cleveland, Ohio

Fig. 14 illustrates this jig with the important dimensions lettered, and Fig. 15 is a chart giving the various dimensions. By means of these dimension sheets the right size of jig can be selected for the job.

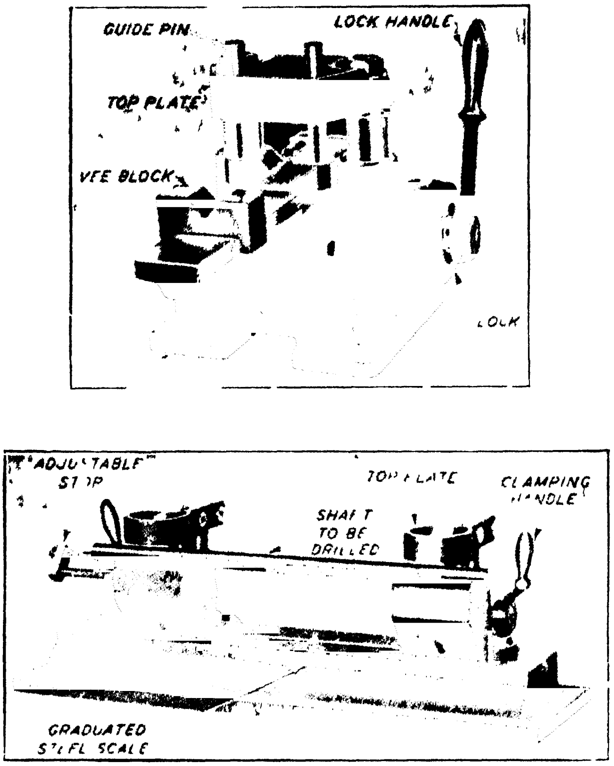


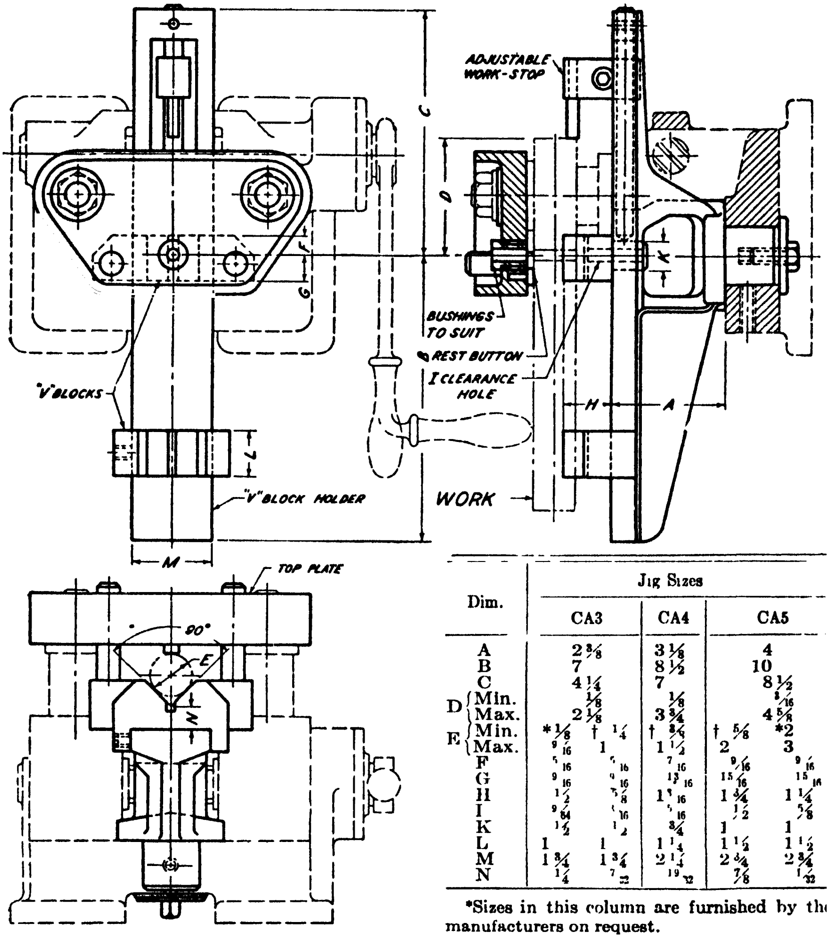
Fig 17. Two Shaft Drilling Jigs Above, Standard Jig for Drilling Shafts. Below, Jig for Drilling Two or More Holes in a Shaft in One Set-up
Courtesy of The Cleveland Universal Jig Co., Cleveland Ohio

Top Plates for Jigs. Various types of top plates have been developed to suit the needs of a majority of plants and these are illustrated in Fig. 16.

Jigs for Drilling Shafts. To drill holes in shafts sometimes offers a problem to the tool designer, particularly when there are various diameters of shafts; usually it has meant the designing of individual jigs for each shaft. Due to the difficulty of having the drill locate exactly in the center of the shaft, and to prevent run *out of the drill, it is necessary to bring the bushing down close to the top of the shaft. A standard design of shaft drilling jig is illustrated* by Fig. 17. With a jig of this type a stationary **V** block would be provided, and also a sliding **V**. An adjustable work stop is provided on the rear end of the jig so that the distance of the hole from the end of the shaft can be accurately held. Rest buttons are placed underneath the top plate of the jig so that the height of the drill bushing to the top of the shaft can be located in such a manner as to prevent the run-out of the drill. By means of a jig of this kind, various sizes of **V** blocks can be interchanged and an extra liner-bushing can be put into the top plate, permitting a number of drill bushings to be used so as to give a variety in the size of holes to be drilled in shafts. These jigs are furnished in several sizes so as to accommodate various diameters of shafts.

Another adaptation of this shaft drilling jig is the one with two smaller jigs on each end of a base, these being adjustable lengthwise, thus permitting two or more holes to be drilled in the shaft at the proper location. A hardened steel scale is mounted on the jig base, measuring any center distance desired within the range of the jig. On some production jobs five or more of these small jigs are mounted on the one base and used on multiple-spindle drill presses, permitting the drilling of all holes in the shaft at one time. Innumerable combinations of this type of tool can be used, depending on the ingenuity of the tool designer. The various sizes and dimensions of these shaft drilling jigs are shown in Fig. 18.

Drill Jigs for Housings. In designing drill jigs for housings of various sorts that have flanged holes and where one side of the casting is machined, it is sometimes necessary to locate the work from the machined surface on the lower part of the bushing plate in a jig. In some cases it would be possible to drill parts of this kind in a jig by locating the machined surface on the bottom portion of the jig; but where the height of the casting is such that it would necessitate the use of extra length drills, it is usually desirable to locate this machined surface of the housing, or a similar part, on the underside of the bushing plate. Therefore, a jig similar to Fig. 19 was developed to permit handling work of this kind. The jig illustrated consists of a cast-iron base, carefully bored to take a plunger. This plunger is operated up and down by means of a pinion shaft which is operated by a lever and locked in place by the toggle lock looated on the side of the jig. The top plate is held in place by means of four posts at the corners of the base, and is fastened by means of hexagon nuts.



Dim.	Jig Sizes				
	CA3		CA4	CA5	
A	2 3/8		3 1/8	4	
B	7		8 1/2	10	
C	4 1/4		7	8 1/2	
D Min.	1/8		1/8	3/16	
D Max.	2 1/8		3 3/4	4 5/8	
E Min.	*1/8	†1/4	†3/8	†5/8	*2
E Max.	9/16	1	1 1/2	2	3
F	5/16	5/16	7/16	9/16	9/16
G	9/16	9/16	13/16	15/16	15/16
H	1/2	5/8	1 3/16	1 3/4	1 1/4
I	9/64	3/16	5/16	1/2	5/8
K	1/2	1/2	3/4	1	1
L	1	1	1 1/4	1 1/2	1 1/2
M	1 3/4	1 3/4	2 1/4	2 3/4	2 3/4
N	1/4	7/32	19/32	7/8	1/32

*Sizes in this column are furnished by th manufacturers on request.

†Sizes in this column are standard V blocks

Fig 18. Details of Shaft Drilling Jigs

Courtesy of The Cleveland Universal Jig Co , Cleveland, Ohio

The locators to position the work properly in the jig are placed on the under side of the top plate. In some instances where holes have already been drilled in the work, the locators can be put into the lower adapter. The top plate has an accurately bored hole that corresponds to the hole in the base of the jig where the plunger is located. This is for construction purposes and provides accurate means of locating the work in the jig. This jig, like the one previously described, is capable of handling any number of pieces of the same over-all length in the one jig by simply changing top plates and lower adapters.

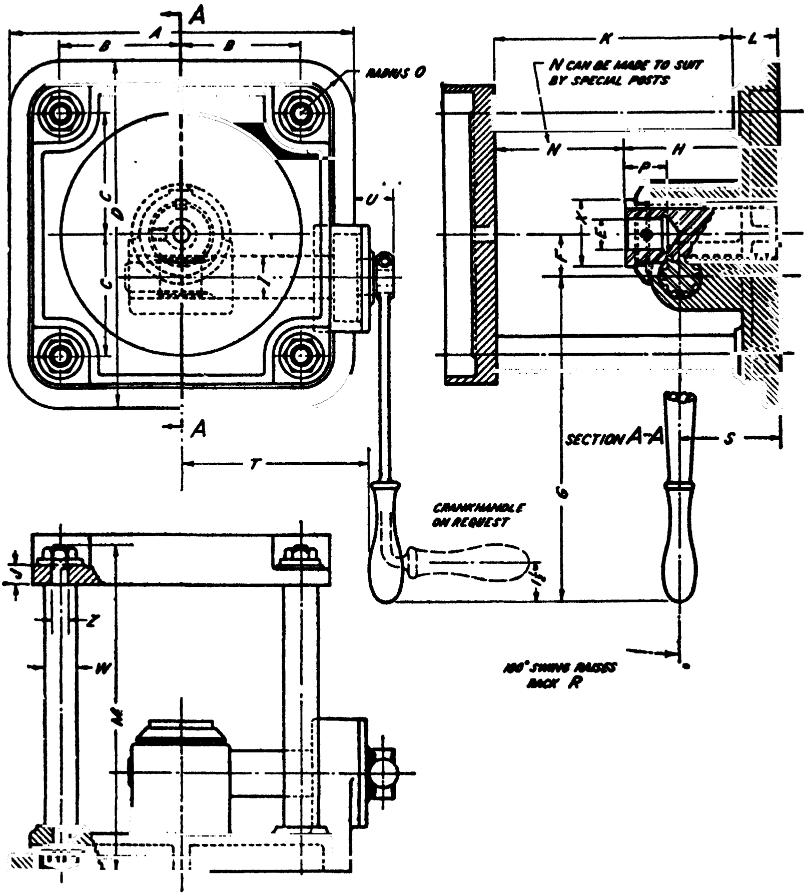


Fig. 19. Dimensions of Drill Jig for Housings
Courtesy of The Cleveland Universal Jig Co., Cleveland, Ohio

Fig. 19 shows this type of jig with the important dimensions lettered. Fig. 20 is a dimension sheet showing the number of sizes and the dimensions that are necessary to enable the designer to select the proper size of jig for the work on hand. Fig. 21 is a chart showing types and sizes of top plates available for this jig.

Fig. 22 shows the application of two Type A and two Type B jigs (see Figs. 14 and 15 and Figs. 19 and 20) for drilling, reaming, hollow-milling and spotfacing lawn mower frames. The work is moved from one jig to the other very rapidly. The loading and unloading time in a setup of this kind requires only a few seconds. This is a high-production job, so special tooling can be used because the cost of machining each piece would be very low in view of the quantities produced.

Jig Dimensions, Inches

Dim.	Jig Sizes						
	B3	B4	B5	B6	B7	B8	B9
A	7 1/8	9 1/2	13	18 1/2	22	26 3/4	34 1/2
B	2.1875	3.000	4 250	6 500	8 000	10.000	13.750
C	2.1875	3 000	4.250	6 500	8 000	10.000	5.750
D	7 1/8	9 1/2	13	18 1/2	22	26 3/4	18 1/2
E	.500	.750	1 000	1 000	1 000	1.000	1.000
F	.750	1.083	1 500	1 500	1.500	1 500	1.500
G	8	10	12	15	18	18	18
H	3 1/8	4 1/8	5 1/2	6 1/4	6 7/8	7 5/8	7 3/8
I	3/4	1 1/4	1 1/2	1 1/2	1 1/2	1 1/2	1 1/2
J	1/2	11/16	13/16	1 1/16	1 1/8	1 3/8	1 1/2
K	4 3/4	7	8 1/2	13	15	21	14
L	1 1/8	1 3/8	1 3/4	2 1/4	2 7/8	3	3 1/4
M	6 3/4	9 9/16	11 5/8	17	19 11/16	26 1/16	19 7/16
N	2 3/4	4 1/4	4 3/4	9	11	16 3/8	9 7/8
O	1 3/8	1 3/4	2 1/4	2 3/4	3	3 3/8	3 1/2
P	7/8	1 1/8	1 1/2	1 1/2	1 1/2	1 1/2	1 1/2
R	1	1 3/4	2	2	2	2	2
S	1 11/16	2 1/2	3 1/8	3 1/2	3 7/8	4 1/8	4 1/4
T	4 1/8	5 5/16	6 3/4	9 15/16	11 5/8	14 1/8	18
U	1 1/2	1 1/2	1 1/4	1 11/16	1 11/16	1 13/16	1 13/16
W	5/8	7/8	1 1/4	1 1/2	1 1/2	1 3/4	1 3/4
X	1 1/4	1 3/4	2 1/4	2 1/4	2 1/4	2 1/4	2 1/4
Z	.4995	.6245	.7495	.9995	.9995	.9995	9995
Size of Lock	No. 10	No. 20	No 20	No. 30	No 30	No 30	No. 30

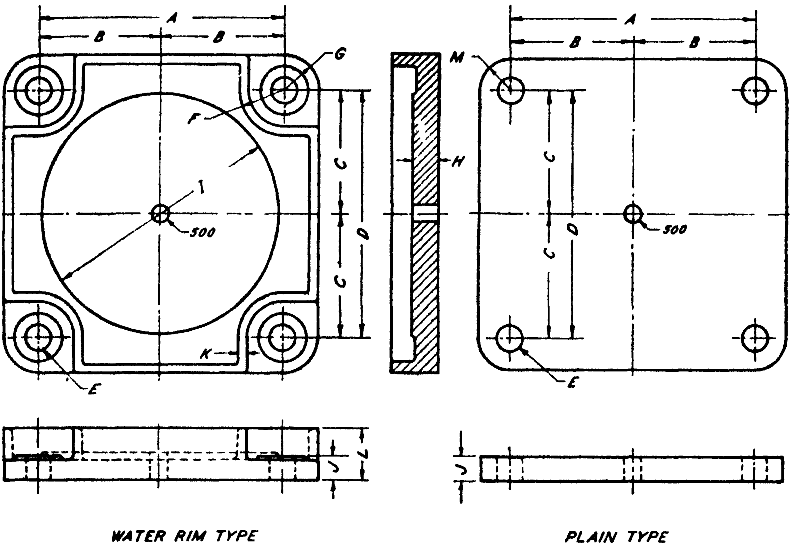
Fig. 20

Courtesy of The Cleveland Universal Jig Co, Cleveland, Ohio

On high-production jobs such as automotive work, standardized drill jigs are used in conjunction with index tables with multiple-spindle drill presses. Fig. 23 illustrates three standardized drill jigs mounted on an index table tooled to drill, ream and countersink five holes in a wheel hub. The operations are as follows: first, load the piece; second, index the table and drill five holes; third, ream and countersink five holes. The cutting tools are made in combination, performing the reaming and countersinking operation at one time. The table is then indexed to the loading position, the work is removed, and a new piece is inserted. After the first pass of the drill head, a part is completed at each index.

In plants that run only a comparatively small number of parts at one time, these standard jigs have proved to be very efficient due to the fact that one of the jig bases can be mounted on the drill press table, and the top plate and lower adapter may be interchanged very rapidly for a large number of jobs. In addition, if a change is made in the design of the part, it is not necessary to scrap the entire jig, as in many cases the adapter could readily be changed to meet the needs of the new part, and the top plate itself could be plugged and the bushing holes relocated to suit the new design.

Top Plates for Jigs



Top-plate No	A	B	C	D	E	F	G	H	I	J	K	L	M
3	4.375	2.1875	2 1875	4.375	.500	15/16	11/16	5/8	4	1/2	1/4	1	1/2
4	6.000	3.000	3.000	6.000	.625	1 1/16	11/16	3/4	6	11/16	1/4	1 1/4	11/16
5	8.500	4.250	4 250	8.500	.750	1 7/16	1 1/16	7/8	8 1/2	13/16	5/16	1 3/4	1
6	13.000	6.500	6.500	13.000	1.000	1 15/16	1 1/8	1 1/4	13	1 1/16	7/16	2 1/4	1 1/16
7	16.000	8.000	8.000	16.000	1.000	2	1 1/8	1 1/4	16	1 1/8	1/2	2 1/4	1 1/16
8	20.000	10.000	10.000	20.000	1.000	2	1 1/4	1 1/2	20	1 3/8	1/2	2 1/4	1 1/4
9	27.500	13.750	5.750	11.500	1.000	2 1/4	1 1/2	1 1/2	11 1/2x 20	1 1/2	3/4	2 1/4	1 1/2

Both water rim type and plain type top plates are made by the manufacturer, and the above dimensions are for both.

Fig. 21. Top Plates for Jigs

Courtesy of The Cleveland Universal Jig Co., Cleveland, Ohio

This type of jig has become widely used during the past several years due to the saving in designing and building time. Of course they cannot be used on all jobs, but where they can be adapted they offer many outstanding advantages.

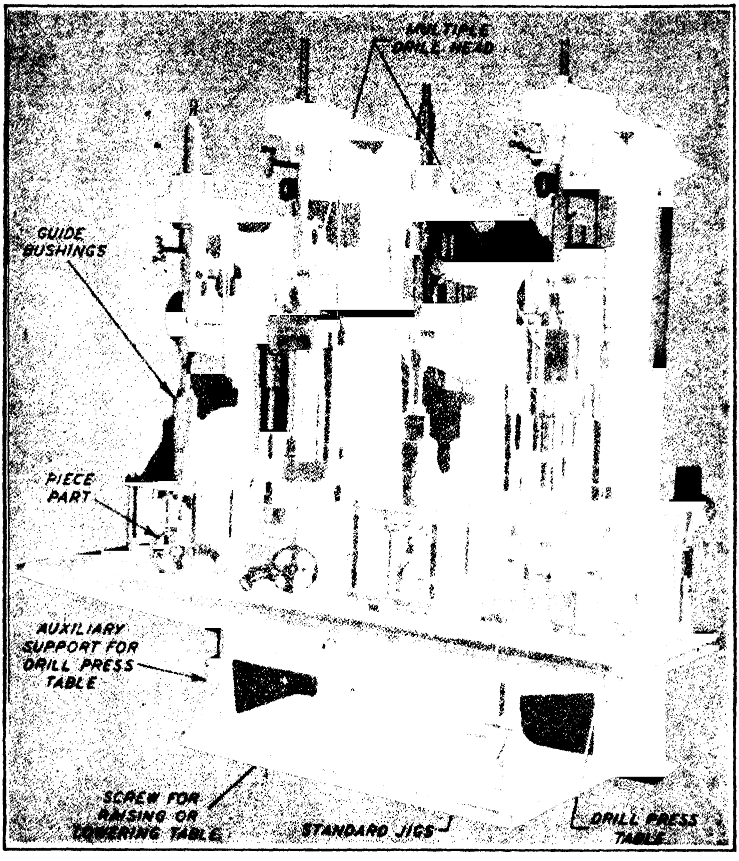

MULTIPLE DRILL HEAD
GUIDE BUSHINGS
PIECE PART
AUXILIARY SUPPORT FOR DRILL PRESS TABLE
SCREW FOR RAISING OR LOWERING TABLE
STANDARD JIGS
DRILL PRESS TABLE

Fig. 22. Four-Spindle Drill Press Equipped with Four Standardized Drill Jigs Tooled to Drill, Ream, Hollow-mill, and Spotface Lawn Mower Frames
Courtesy of The Cleveland Universal Jig Co., Cleveland, Ohio

Automatic Locks. On large work where it is necessary to design jigs and fixtures in order to obtain interchangeability and low cost, it is necessary to have some means of positioning the castings in the jigs or fixtures; also, positive locking means must be provided. Formerly this was accomplished by means of levers, or screws with a handwheel attached in order to obtain the required pressure. These methods were slow and in some cases very inconvenient. Therefore, an automatic lock was developed to take the place of various other means of positioning large work in jigs and

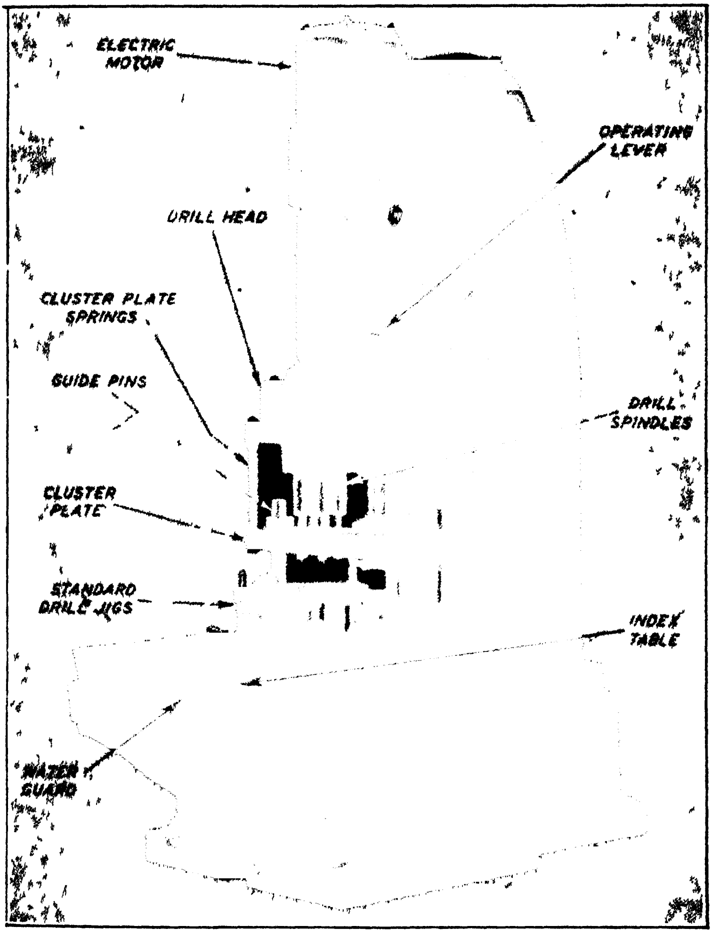
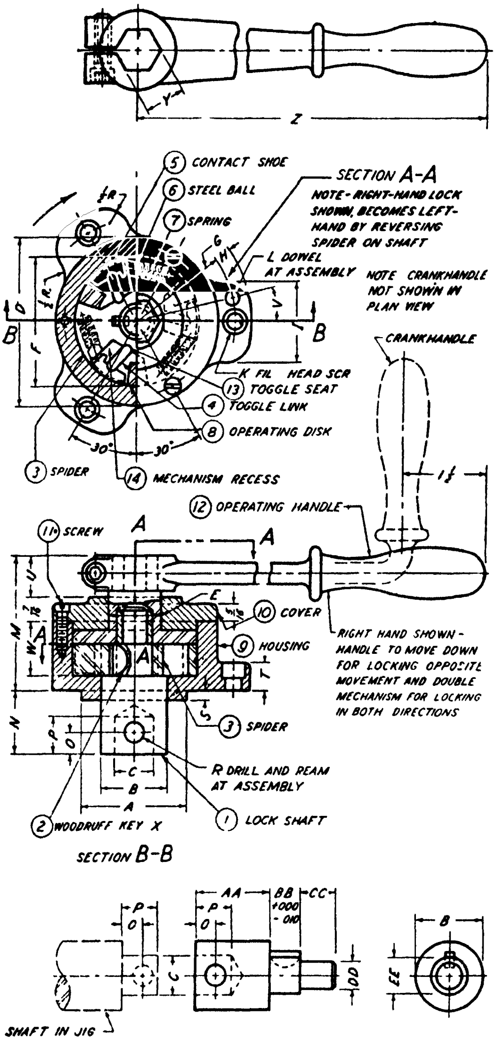


Fig. 23. Multiple-Spindle Drill Press Equipped with Index Table Having Three Standard Drill Jigs

Courtesy of The Cleveland Universal Jig Co., Cleveland, Ohio

fixtures. This lock is designed so that it can operate jack screws for raising large work into position, or lock the work against a definite stop. It is also used on conventional types of jigs and fixtures to hold work in proper position.

Fig. 24 describes a lock of this type and shows a detailed drawing and the various sizes and dimensions. The operation of the lock



Automatic Locks

Dim.	Lock Sizes			
	L10	L20	L30	L40
A	2 000	2.750	2.750	3.500
B	1.250	1 500	1 500	1 750
C	750	1 000	1 000	1 250
D	3⅛	3¾	4¾	5¼
E	1	1 5/16	1½	1¾
F	2 375	3 000	3 500	4 000
G	1⅞	2 3/16	2¾	3
H	⅜	7/16	7/16	½
I	1⅞	2	2½	3
K	5/16	5/16	⅜	⅜
L	¼	¼	5/16	⅜
M	2 9/16	2⅝	2 15/16	3 5/16
N	1 3/16	1 3/16	1 3/16	1¼
O	7/16	7/16	7/16	⅝
P	¾	⅞	⅞	1¼
R	5/16	⅜	⅜	½
S	3/16	3/16	3/16	¼
T	½	½	⅝	¾
U	⅞	15/16	1	1⅛
V	16°	15°	14°	14°
W	1	1	1⅛	1⅜
X	#6	#9	"A"	"B"
Y	¾	¾	⅞	⅞
Z	*8 or 10	10 *12 or 15	12 *15 or 18	15 *18 or 22
AA	1 7/16	1 7/16	1 9/16	1⅝
BB	9/16	9/16	⅝	¾
CC	⅝	¾	¾	1
DD	500	.750	750	.875
EE	6255	8755	1 0005	1 3755

Fig. 24. Details, Sizes and Dimensions for Automatic Locks
Courtesy of The Cleveland Universal Jig Co., Cleveland, Ohio

is as follows: The shaft (*1*) which is to be alternately rotated and stopped, has a spider (*3*) keyed on by a Woodruff key (*2*). The spider has three mechanism recesses (*14*) which contain the locking mechanism. Operating disc (*8*) is freely mounted on shaft (*1*), and has three prongs reaching into the mechanism recesses (*14*).

The rounded ends of the toggle link (*4*) fit into contact shoe (*5*) and toggle seat (*13*). Through steel ball (*6*), a spring (*7*) forces the contact shoe (*5*) against the housing (*9*).

By looking at the drawing, it can readily be seen that the shaft (*1*) cannot rotate in the direction of the arrow because contact shoe (*5*) with toggle link (*4*) is jammed against the housing, holding spider (*3*) in place. The shaft is positively locked at all times until operating disc (*8*) is moved.

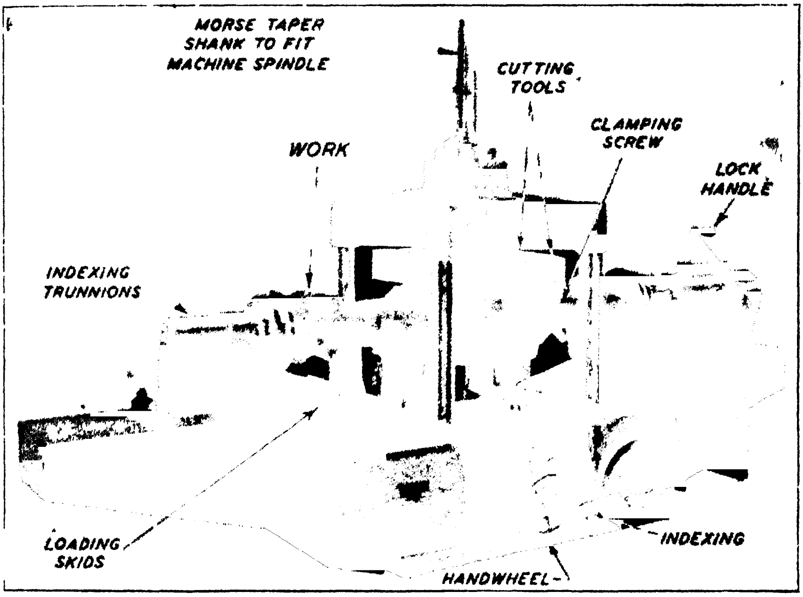
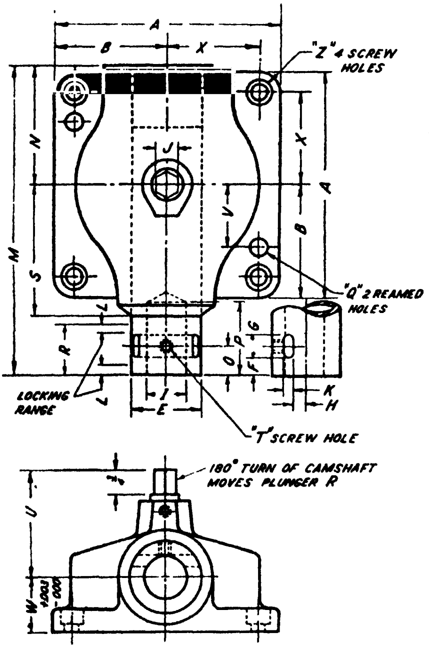


Fig 25 Special Fixture Equipped with Automatic Lock for Machining Center Section of Axle Housing

Courtesy of The Cleveland Universal Jig Co, Cleveland, Ohio

Operating disc (*8*) with operating handle (*12*) controls the movements of shaft (*1*). If the operating disc is turned to the left, the prongs of the disc will rest on the spider (as shown) and rotate shaft (*1*) in the opposite direction, shown by arrow. By rotating the operating disc to the right, the prongs push the contact shoes against the spider and rotate the shaft in the direction of the arrow.

These locks have almost unlimited application on various types of jigs and fixtures. Fig. 25 *illustrates an application of these locks* on a large fixture for machining the center section of the cast steel truck axle housing. In this fixture the location is taken off the end bores and the part is squared by locating jacks in the center of the fixture. This also squares the part on the finished boss. The center section of this housing is faced both top and bottom. The facing head is lifted high enough to clear while the work is reversed for facing on the opposite side. This axle housing is revolved by means of a worm-gear attachment, shown in the extreme right-hand side of the illustration.



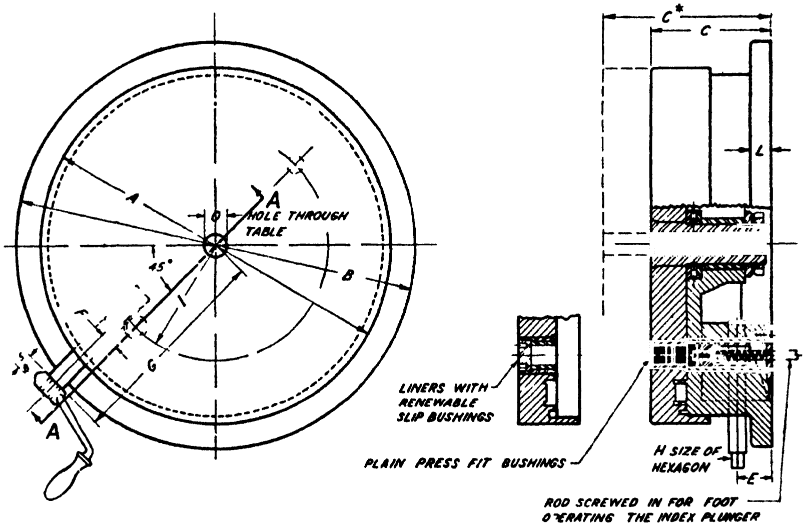
Cam Locks

Dim.	Lock Sizes, Inches				
	CRA2	CRA3	CRA4	CRA5	CRA7
A	3 7/8	4 5/8	5 7/8	6 5/8	8 1/8
B	1 15/16	2 5/16	2 15/16	3 5/16	4 1/16
E	1 1/4	1 5/8	2	2 1/2	3
F	3/8	1/2	1/2	5/8	13/16
G	1/2	5/8	5/8	3/4	7/8
H	1/8	3/16	3/16	1/4	3/8
I	750	1.000	1.000	1.250	1.500
J	5/8	5/8	3/4	3/4	7/8
K	1/4	5/16	5/16	3/8	7/16
L	7/64	1/8	11/64	13/64	1/4
M	5 7/16	6 13/16	8 1/8	9 5/16	11 7/16
N	2 1/16	2 1/2	3 1/16	3 1/2	4 1/4
O	5/8	13/16	13/16	1	1 1/4
P	1 5/8	2 1/8	2 1/8	2 1/2	3
Q	5/16	3/8	7/16	1/2	1/2
R	3/4	1	1 3/8	1 5/8	2
S	2 3/8	3	3 1/2	4	5
T	1/4	5/16	5/16	3/8	7/16
U	2 13/16	3	3 1/4	3 7/8	4 1/8
V	1 1/16	1 5/16	1 11/16	1 15/16	2 5/16
W	1 3/16	1 5/8	1 13/16	2 1/8	2 9/16
X	1 9/16	1 7/8	2 7/16	2 3/4	3 3/8
Z	1/4	5/16	3/8	7/16	1/2

Fig. 26
Courtesy of The Cleveland Universal Jig Co., Cleveland, Ohio

In some of the large tractor plants, locks of this type are used in conjunction with loading mechanisms, particularly on transmission housings where these parts are machined on several sides by means of multiple-spindle drill heads. Due to the weight of the transmission housings, it is necessary to move these pieces from one station of the machine to the other by means of a roller conveyor;

Index Tables


C*
C
L
A
A
O
HOLE THROUGH TABLE
45°
B
I
F
G
A
LINERS WITH RENEWABLE SLIP BUSHINGS
PLAIN PRESS FIT BUSHINGS
H SIZE OF HEXAGON
E
ROD SCREWED IN FOR FOOT OPERATING THE INDEX PLUNGER

A	B	C	C*	E	F	G	H	I	L	O
8	9 1/4	3 1/4	5 1/4	1	11/16	4 7/8	1/2	2 5625	1/2	500
10	11 1/4	3 1/2	5 1/2	1 1/16	11/16	5 7/8	1/2	3 3750	9/16	625
12	13 1/2	3 3/4	5 3/4	1 1/8	3/4	7	1/2	4 0625	5/8	750
14	15 3/4	4	6	1 1/4	3/4	8 1/8	5/8	4 5625	3/4	875
16	17 3/4	4	6	1 1/4	3/4	9 1/8	5/8	5 3125	3/4	875
18	20	4 1/2	6 1/2	1 5/16	27/32	10 5/16	5/8	6 0000	13/16	875
20	22 1/4	5	7	1 3/8	7/8	11 7/16	5/8	6 8750	7/8	875
24	26 1/2	6	8	1 5/8	1	13 5/8	3/4	8 3125	1	1 000
30	33	7	9	2	1 1/16	17 1/16	3/4	10 9375	1 1/4	1 000
36	39 1/2	8	10	2 1/8	1 3/16	20 5/16	3/4	13 1875	1 3/8	1 000
40	43 1/2	8	10	2 3/16	1 5/16	22 7/16	3/4	14 6875	1 3/8	1 500
48	52	9	11	2 3/8	1 3/8	26 3/4	3/4	18 5000	1 1/2	1 500

The dimensions shown in Column *C* are for low style tables, those in column *C** are for high style tables

Fig 27

Courtesy of The Cleveland Universal Jig Co, Cleveland, Ohio then they are pushed into position and raised to the proper height by means of these automatic locks; then located in the jig for the drilling operation. This saves considerable manual labor and is less fatiguing to the operator.

Cam Locks. Another type of lock that has come into general use during the past few years is a cam lock. These locks are used on all types of jigs and fixtures for clamping and positioning the work. Cam locks are of very simple construction, are easy in operation, and are readily adaptable to any type of jig and fixture requiring quick and powerful clamping facilities. They contain only two moving parts, the clamping plunger and a cam to operate it. The cam is hardened and ground and operates between hardened and ground surfaces of the plunger. Fig. 26 illustrates these cam locks and gives a chart showing the sizes regularly furnished.

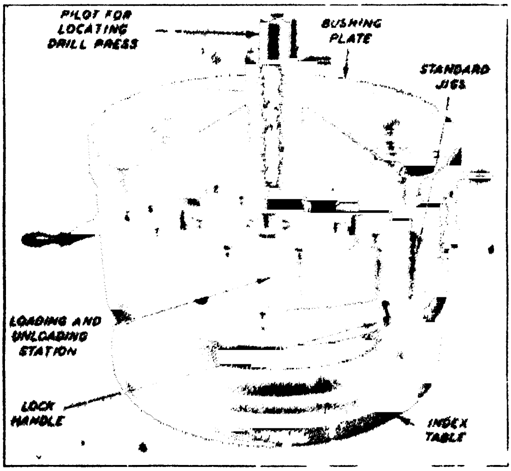


Fig 28. Index Table with Four Jigs, Used with Multiple-Spindle Drill Press

Courtesy of The Cleveland Universal Jig Co., Cleveland, Ohio

Index Tables. Index tables have come into considerable use on high-production jobs, particularly where they can be used under multiple drill presses. By mounting two or more jigs on an index table it is possible to step up production considerably, as different groups of holes can be drilled in the same piece part by indexing the jigs from one position under the spindles to another.

Fig. 27 illustrates an index table that has just been developed for use on drill presses, milling machines, or boring mills. These tables are regularly furnished in sizes from 8″ to 48″ and are made in the plain and water-rim types. This latter is used where it is necessary to provide a lubricant or coolant for the cutting tools. This type of index table rotates very freely, as it is located on precision rollers which are guided by a retainer ring and are run on hardened and ground races.

For milling machines, these index tables are furnished with a locking mechanism for holding the table top firmly on the base, thus eliminating vibration. For use on drill presses this locking mechanism is not required.

These index tables can be provided with as many index positions as are required. The common practice is to put approximately 3 to 4 stations on one of these index tables, depending on the size, having one station as a loading and unloading station. Fig. 28 shows one of these index tables with four cam-operated fixtures to be used in a multiple-spindle drill press.

DIE SETS AND ACCESSORIES

For a great many years the majority of metal manufacturing plants which used dies on their production, designed and built their own die sets. This was a very expensive process because in many instances only a few dies were built at a time. The lack of standards meant that a great number of patterns accumulated; for, every time it was necessary to design a die, new patterns would have to be built in order to obtain castings for the punch and die holder. Of course in some of the larger plants some attempts were made at standardization, and patterns were altered to suit the needs of the particular job. In the event a new punch press was ordered, it was often found that the old dies would not fit in the new press until extensive alterations had been made. This went on for some time, until it became apparent that die sets of better quality would have to be obtained. A great many dies were made without leader pins and due to the demands of high production it was found necessary to incorporate leader pins and bushings in die sets to obtain proper alignment in setting up the die in the punch press.

Another factor that caused a change to better quality and more accurate die sets was the development of stampings for parts to replace castings that were formerly used. In many instances stampings were considerably cheaper and lighter than castings. In addition, the speed with which these stamped parts could be produced on a punch press, and their low cost, made it imperative to develop ways and means of standardizing die sets. At the present time the majority of metal manufacturing plants using dies on their own production, purchase die sets from one of the several manufacturers of these items. It is now possible to obtain, from the manufacturer's stock, practically every size and type of die set required by the average metal working plant. Their catalogs list all of these sizes with dimensions, enabling the tool designer to choose instantly the size and type of die set covering the particular die he is going to design. On some of the very large dies, the die sets are fabricated from tank plate by means of the cutting torch, and the leader pins and guide bushings are then purchased from the die set manufacturer

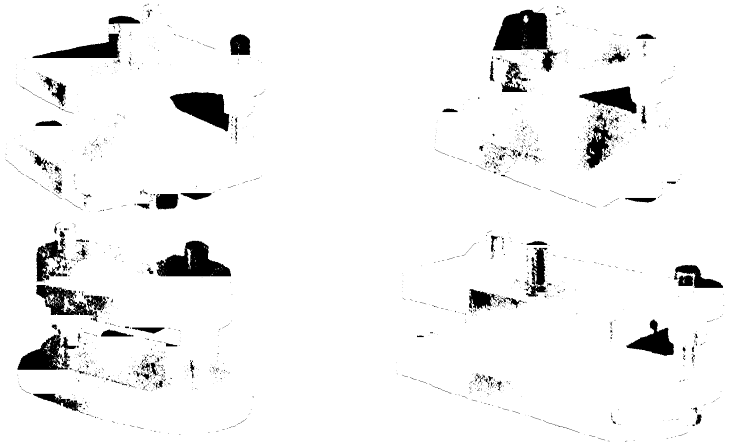
Die Sets. Fig. 29 illustrates a few of the several types of die sets that are standard. These can be obtained in semisteel, which is a mixture of steel and cast iron. Usually 20% to 25% steel scrap is contained in the analysis of semisteel. The steel die sets are usually made from forged steel or from tank plate.

Fig. 30 presents a drawing of a standard back post die set and gives the general dimensions of several sizes. These dies sets are assembled complete with guide post and bushing, the latter being hardened, ground and lapped. In the event it would be necessary to have larger or longer guide posts and bushings, these can also be furnished at a slight additional cost over the standard price. The trend today is toward steel die sets because they are lighter and stronger than those made of cast iron or semisteel.

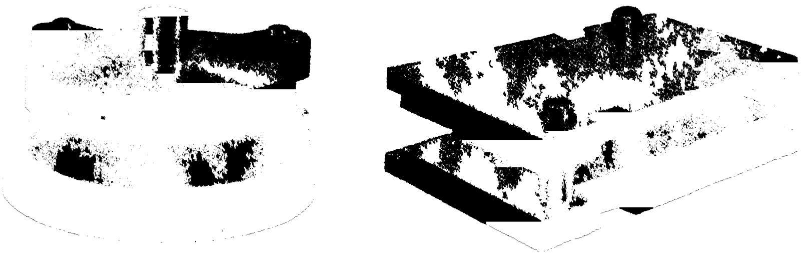
In using a die set, the tool designer specifies the diameter of the punch shank, over-all length of the guide post, and the type of bushings desired. On the die sets shown in Fig. 30 the punch shanks can be obtained in the following sizes:

1½" diameter x 2⅛" long
1$\frac{9}{16}$" diameter x 2⅛" long
2" diameter x 2⅞" long
2½" diameter x 2⅞" long
3" diameter x 2⅞" long

or special shanks can be furnished at a nominal extra charge; or, in the event the punch holder is to be fastened directly to the ram of the punch set, these sets can be obtained without the punch shank The thickness of the punch and die holders can be increased if it is desired, but the sizes that are regularly listed in the catalog can be obtained immediately from the manufacturers' stock.



Semisteel and Steel

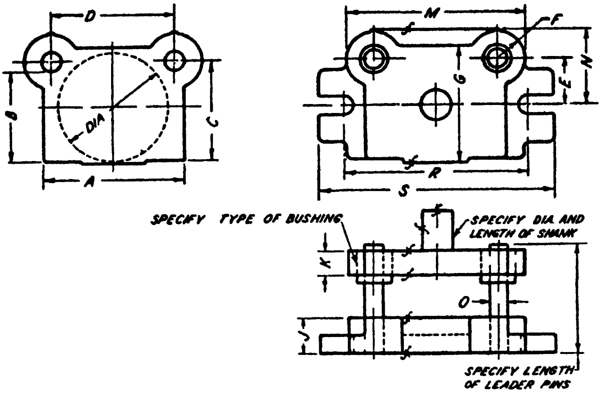


Semisteel and All-Steel

Fig 29. Typical Standard Die Sets
Courtesy of Danly Machine Specialties, Inc , Chicago, Ill

Fig. 31 illustrates a few of the several other types of die sets made which permit a wide choice. The four-post die sets are generally used in conjunction with dies that are designed for heavy-duty work, or where extreme accuracy is required and it would be necessary to make sure that the punch section of the die was in perfect alignment with the die section. On heavy work there is always a possibility of a punch being forced to one side or the other, which would cause difficulty because if the punch itself should come in contact

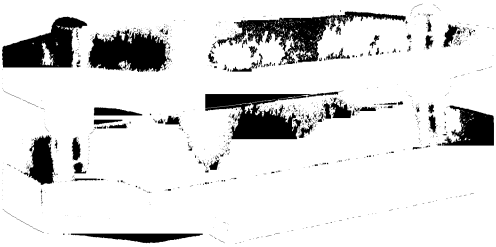
Standard Back Post Sets


D
B
C
DIA
A
M
F
N
E
G
R
S
SPECIFY TYPE OF BUSHING
SPECIFY DIA. AND LENGTH OF SHANK
K
O
J
SPECIFY LENGTH OF LEADER PINS

Die Space		Dia	Thickness		General Dimensions Inches									
Left to Right	Front to Back	For Round Dies	Die Holder	Punch Holder										
A	B	Dia	J	K	C	D	E	F	G	M	N	O	R	S
8 1/2	6 1/4	7	1 1/2	1 1/4 1 3/4 2 1/4	6 3/4	7 3/4	3 1/8	1 3/8	7 3/8	10 5/8	4 9/16	1	10 3/4	13 1/4
			2 1/4	1 1/4 1 3/4 2 1/4										
			2 3/4	1 1/4 1 3/4 2 1/4										
8 1/2	8	8 1/2	1 1/2	1 1/4 1 3/4 2 1/4	8 1/2	7 3/4	4 3/16	1 3/8	9 5/16	10 5/8	5 7/8	1	10 3/4	13 1/4
			2	1 1/4 1 3/4 2 1/4										
			2 1/2	1 1/4 1 3/4 2 1/4										
8 1/2	11		1 3/4	1 1/2 2 1/4	11 5/8	10 1/4	5 3/4	1 7/8	12 1/2	13 5/8	7 7/16	1 1/4	10 3/4	13 1/4
			2 1/2	1 1/2 2 1/4										
10	3 1/2		1 1/2	1 1/4 1 3/4	4 1/16	9 1/8	2 1/4	1 1/2	4 3/4	12 1/4	3 3/4	1 1/8	12 1/4	14 7/8
			2	1 1/4 1 3/4										
10	5 1/4		1 1/2	1 1/4 1 3/4	5 13/16	9 1/8	3 5/16	1 1/2	6 1/2	12 1/4	4 13/16	1 1/8	12 1/4	14 7/8
			2	1 1/4 1 3/4										
			2 1/2	1 1/4 1 3/4										
10	6 3/4		1 5/8	1 3/8 1 3/4 2 1/4	7 5/16	9 1/8	3 9/16	1 7/16	8	12 1/8	5 1/16	1 1/8	12 1/4	14 7/8
			2 1/4	1 3/8 1 3/4 2 1/4										
			2 3/4	1 3/8 1 3/4 2 1/4										

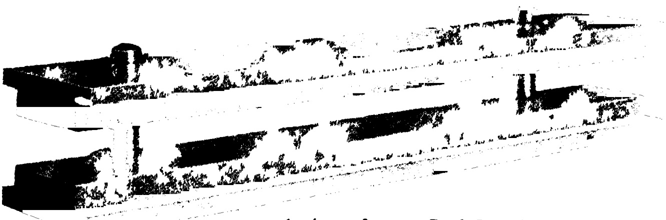
Fig 30

Courtesy of Danly Machine Specialties, Inc , Chicago, Ill

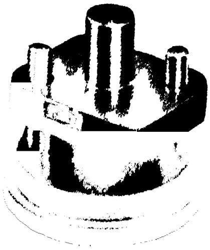


A Rectangular Two Post Set, Center Post. Furnished also in Back-Post and in Diagonal Post Styles

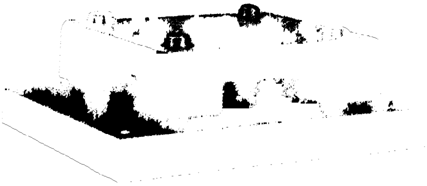
B Four Post Set



C Long Narrow Back Post Set



D Combination Diagonal-Post Set



E Special Set

Fig 31 Typical Large Semisteel Die Sets

Courtesy of Danly Machine Specialties, Inc., Chicago, Ill with the *die block (both of these being* **hardened)** **one** or the other *would be broken.*

On some jobs, particularly where it would be necessary to punch and notch, angle-iron long, narrow, back posts sets are used. This type of die set is often used in a press brake instead of a punch press for fabricating long parts that may be pierced, notched or formed.

Bolster Plates. In many plants using dies for their regular production, bolster plates for the one punch press are sometimes necessary due to the design and construction of dies. They are now furnished as standard, and various sizes can be obtained readily from the manufacturer of die sets and accessories. These can be obtained either in cast iron or steel. Various size holes can be cast or cut into these bolster plates to suit the needs of the job on which they are to be used.

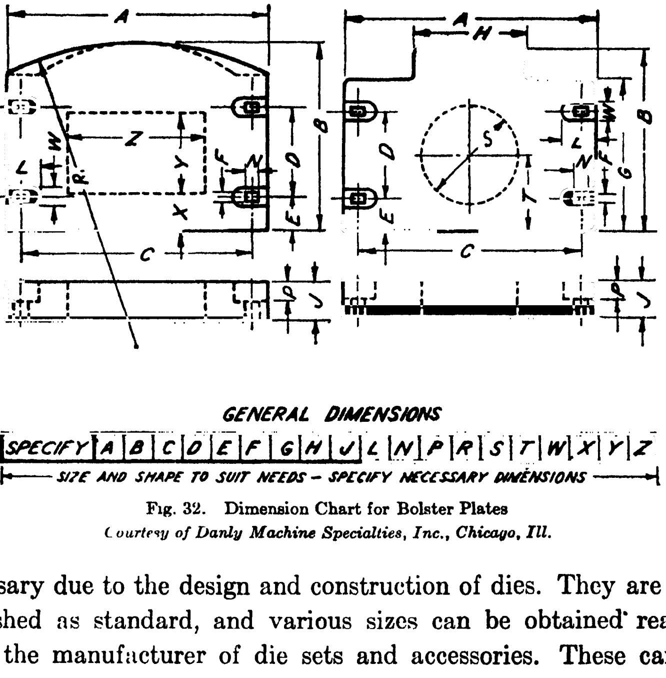

A
A
H
B
B
D
D
E
E
G
G
F
L
L
N
N
W
W
Z
Y
X
R
S
K
C
C
J
J
T
T
GENERAL DIMENSIONS
SPECIFY
A B C D E F G H J L N P R S T W X Y Z
SIZE AND SHAPE TO SUIT NEEDS - SPECIFY NECESSARY DIMENSIONS

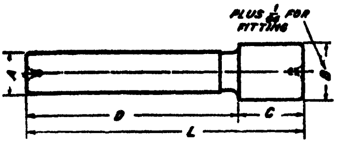
Fig. 32. Dimension Chart for Bolster Plates
Courtesy of Danly Machine Specialties, Inc., Chicago, Ill.

Fig. 32 shows a dimension chart of these bolster plates. In ordering a plate, the tool designer makes a layout similar to what is shown in Fig. 32 and puts in the necessary dimensions.

Shoulder Guide Posts and Guide-Post Bushings. Where it is desirable to design and build die sets in the plant in order to accommodate some special job, standard guide posts and guide-post bush-

Shoulder Guide Post and Guide-Post Bushings

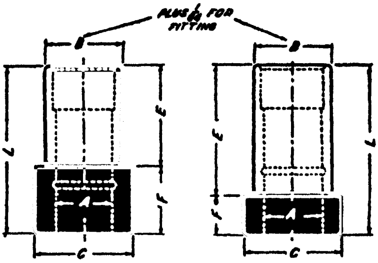
Shoulder Guide Posts



Diameter "A" of guide post finish ground to +.0004" −.0000" of listed diameter.

Dia., Inches		Length, Inches		
A	B	L	C	D
1	1½	4½ 5 5½ 6 6½ 7 7½ 8	1½	3 3½ 4 4½ 5 5½ 6 6½
1¼	1¾	5 5½ 6 6½ 7 7½ 8 8½ 9	2	3 3½ 4 4½ 5 5½ 6 6½ 7
1½	2	7 7½ 8 8½ 9 9½ 10	2⅜	4⅝ 5⅛ 5⅝ 6⅛ 6⅝ 7⅛ 7⅝
1¾	2¼	7½ 8 8½ 9 9½ 10	2⅞	4⅝ 5⅛ 5⅝ 6⅛ 6⅝ 7⅛
2	2½	8 9 10 11 12 13	3⅜	4⅝ 5⅝ 6⅝ 7⅝ 8⅝ 9⅝
2½	3	9 10 11 12 13 14	3⅞	5⅛ 6⅛ 7⅛ 8⅛ 9⅛ 10⅛

Steel Shoulder Guide Post Bushings



Inside diameter of 1", 1¼", 1½" and 1¾" bushings, ground and honed to +.0003" −.0002", 2" and 2½" diameter bushings finish ground to +.0003" −.0002" of listed decimal inside diameter.

A		B	C	E	F	L
Nom.	Dec.					
1	1.0021	1½	1¹¹⁄₁₆	1¼ 2	1¼ ½	2½
1¼	1.2526	1¾	1¹⁵⁄₁₆	1⅝ 2⅝	1½ ½	2⅞
1½	1.5026	2	2³⁄₁₆	1½ 2½	1½ ½	3
1¾	1.7526	2¼	2½	1¾ 2½	1½ ¾	3¼
2	2.005	2½	3⅛	2 2¾	1½ ¾	3½
2½	2.5062	3	3⅝	2 3	2 ¾	4 3¾

Cast Alloy Shoulder Guide Post Bushings

Finished to within ±.0005" of listed decimal inside diameter.

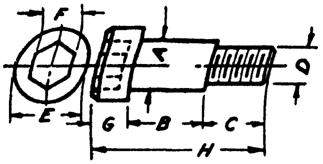
A		B	C	E	F	L
Nom.	Dec.					
1	1.0021	1½	1¾	1¼ 2	1¼ ½	2½
1¼	1.2526	1¾	2	1⅜ 2⅜	1½ ½	2⅞
1½	1.5026	2	2⅜	1½ 2½	1½ ½	3
1¾	1.7526	2¼	2⅝	1¾ 2½	1½ ¾	3¼
2	2.005	2½	3⅛	2 2¾	1½ ¾	3½
2½	2.5062	3	3⅝	2 3	2 ¾	4 3¾

Fig. 33

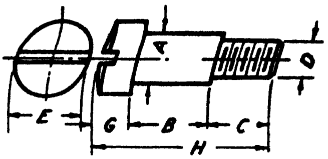
Courtesy of Danly Machine Specialties, Inc., Chicago, Ill.

ings are furnished in a wide variety of sizes. Fig 33 illustrates these items and presents a chart showing some of the sizes in which they are regularly obtainable. There are several additional types of guide

Socket Head Stripper Bolts



Socket Head Stripper Bolt



Fillister Head Stripper Bolt

Body		C	D	E	F	G	H	U.S.S. Thd.
Dia. A	Lgth. B							
⅜	1	½	5/16	9/16	3/16	¼	1¾	18
	1¼						2	
	1½						2¼	
	1¾						2½	
	2						2¾	
	2¼						3	
	2½						3¼	
	2¾						3½	
	3						3¾	
	3¼						4	
	3½						4¼	
	3¾						4½	
	4						4¾	
½	1	⅝	⅜	¾	¼	5/16	1 15/16	16
	1¼						2 3/16	
	1½						2 7/16	
	1¾						2 11/16	
	2						2 15/16	
	2¼						3 3/16	
	2½						3 7/16	
	2¾						3 11/16	
	3						3 15/16	
	3¼						4 3/16	
	3½						4 7/16	
	3¾						4 11/16	
	4						4 15/16	
	4¼						5 3/16	
	4½						5 7/16	
	4¾						5 11/16	
	5						5 15/16	
⅝	1¼	¾	½	⅞	5/16	⅜	2⅜	13
	1½						2⅝	
	1¾						2⅞	
	2						3⅛	
⅝	2¼	¾	½	⅞	5/16	⅜	3⅜	13
	2½						3⅝	
	2¾						3⅞	
	3						4⅛	
	3¼						4⅜	
	3½						4⅝	
	3¾						4⅞	
	4						5⅛	
	4¼						5⅜	
	4½						5⅝	
	4¾						5⅞	
	5						6⅛	
	5½						6⅝	
	6						7⅛	
¾	1½	⅞	⅝	1	⅜	½	2⅞	11
	1¾						3⅛	
	2						3⅜	
	2¼						3⅝	
	2½						3⅞	
	2¾						4⅛	
	3						4⅜	
	3¼						4⅝	
	3½						4⅞	
	3¾						5⅛	
	4						5⅜	
	4¼						5⅝	
	4½						5⅞	
	4¾						6⅛	
	5						6⅜	
	5½						6⅞	
	6						7⅜	
	6½						7⅞	
	7						8⅜	

Fillister Head Stripper Bolts

Body		C	D	E	G	H	U.S.S. Thd.
Dia. A	Lgth. B						
⅜	1	½	5/16	9/16	⅜	1⅞	18
	1¼					2⅛	
	1½					2⅜	
	1¾					2⅝	
	2					2⅞	
	2½					3⅜	
	3					3⅞	
	3½					4⅜	
½	1½	⅝	⅜	¾	½	2⅝	16
	1¾					2⅞	
	2					3⅛	
	2½					3⅝	
	3					4⅛	
	3½					4⅝	
	4					5⅛	
⅝	2	¾	½	⅞	⅝	3⅜	13
	2½					3⅞	
	3					4⅜	
	3½					4⅞	
	4					5⅜	
	5					6⅜	
	6					7⅜	
¾	3	⅞	⅝	1	¾	4⅝	11
	3½					5⅛	
	4					5⅝	
	5					6⅝	
	6					7⅝	
	7					8⅝	
	8					9⅝	
	.....					....	

Fig. 34

Courtesy of Danly Machine Specialties, Inc., Chicago, Ill.

posts and guide-post bushings which are to be found in the manufacturers' catalogs.

Stripper Plates. *In designing and building dies it is necessary* to provide strippers in order to pull the material being punched or formed off the punches. A stripper plate is used and this is fastened to the punch holder by means of stripper bolts.

Stripper Bolts. This is a bolt with a thread and a shoulder so that springs can be put over the body of the bolt that is used to hold the stripper plate to the punch holder. Stripper bolts were formerly made in the average plant tool room and were quite expensive. They now can be obtained at approximately one-half that cost from the manufacturers of die sets and accessories.

Fig. 34 illustrates two types of stripper bolts; one is a socket head type and the other a standard fillister head type. The charts show the various sizes in which these can be regularly furnished.

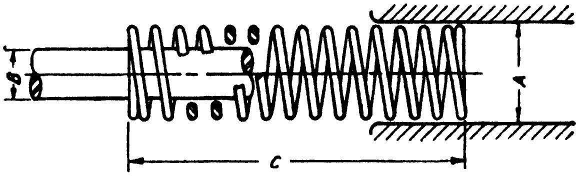
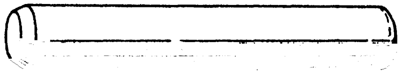


Fig. 35. Die Spring of Round Spring Stock
Courtesy of Danly Machine Specialties, Inc., Chicago, Ill.

Die Springs. To strip work from punches and to form work on pressure pads, springs are necessary. These are furnished in numerous types, the spring stock being either round, flat or square. Fig. 35 shows a die spring of round spring stock. These springs are also furnished in medium pressure high deflection or high pressure medium deflection. The development of metal stamping in industry has required a wide range of springs to suit the need. Die springs must be of high quality to meet the requirements in the severe service that they undergo in punch-press operations. Therefore it is important to select the proper pressure of spring in order that the die may function properly. The manufacturer's catalog completely illustrates the various ranges, sizes, and types of springs that can be obtained from their stock. Therefore one of these catalogs is an essential part of the equipment of the tool designer engaged in designing dies.

Precision Dowel Pins



Standard Size		Standard Size		Oversize (.001")		Oversize (.001")	
Diameter Inches	Length Inches	Diameter Inches	Length Inches	Diameter Inches	Length Inches	Diameter Inches	Length Inches
1/8	1/2 3/4 1	3/8	1 3/4 2 2 1/4 2 1/2	1/8	1/2 3/4 1	3/8	1 3/4 2 2 1/4 2 1/2
3/16	1/2 3/4 1 1 1/4 1 1/2 1 3/4 2	7/16	1 1/2 2 2 1/2	3/16	1/2 3/4 1 1 1/4 1 1/2 1 3/4 2	7/16	1 1/2 2 2 1/2
1/4	1/2 3/4 1 1 1/4 1 1/2 1 3/4 2	1/2	1 1/2 1 3/4 2 2 1/4 2 1/2 2 3/4 3 3 1/2 4	1/4	1/2 3/4 1 1 1/4 1 1/2 1 3/4 2	1/2	1 1/2 1 3/4 2 2 1/4 2 1/2 2 3/4 3 3 1/2 4
5/16	1/2 3/4 1 1 1/4 1 1/2 1 3/4 2 2 1/4 2 1/2	5/8	2 2 1/2 3 3 1/2 4	5/16	1/2 3/4 1 1 1/4 1 1/2 1 3/4 2 2 1/4 2 1/2	5/8	2 2 1/2 3 3 1/2 4
3/8	1 1 1/4 1 1/2	3/4	2 2 1/2 3 4	3/8	1 1 1/4 1 1/2	3/4	2 2 1/2 3 4
		7/8	2 1/2 3 4			7/8	2 1/2 3 4

Fig 36

Courtesy of Danly Machine Specialties, Inc , Chicago, Ill

Dowel Pins. In designing and building dies, tools, jigs, fixtures, etc., a great many dowel pins are used to locate the various parts in proper relation to each other. Formerly, dowel pins were made in the average tool room from drill rod; in some instances these were hardened and oftentimes some distortion would take place during the hardening, causing trouble in assembling parts on tools and dies. Today, dowel pins in practically the entire range of sizes that would ordinarily be required in the plant tool room can be obtained from manufacturers of this item. Fig. 36 illustrates standard dowel pins and gives the sizes in which they can regularly be obtained. These are hardened and ground to insure close accuracy. They are furnished in both standard sizes and in oversize to .001" to insure a drive fit or for use where it is necessary to use an oversize dowel pin on repair work or to renew parts.

Automatic Stock Feed Stops. In designing and building dies, it is often necessary to include stops for the material that is being punched or stamped. Automatic stock feed stops, Fig. 37, are widely used on some types of blanking operations to automatically stop the stock in the correct position just prior to piercing, shearing, or blanking operations. These automatic stops speed production, reduce waste of materials, and eliminate considerable spoilage that might be due to carelessness or poor judgment. These automatic stops are designed so that they can easily be applied to almost any type of blanking die, whether it is a simple, progressive, or compound die. The wearing parts on these stops are all hardened to resist wear.

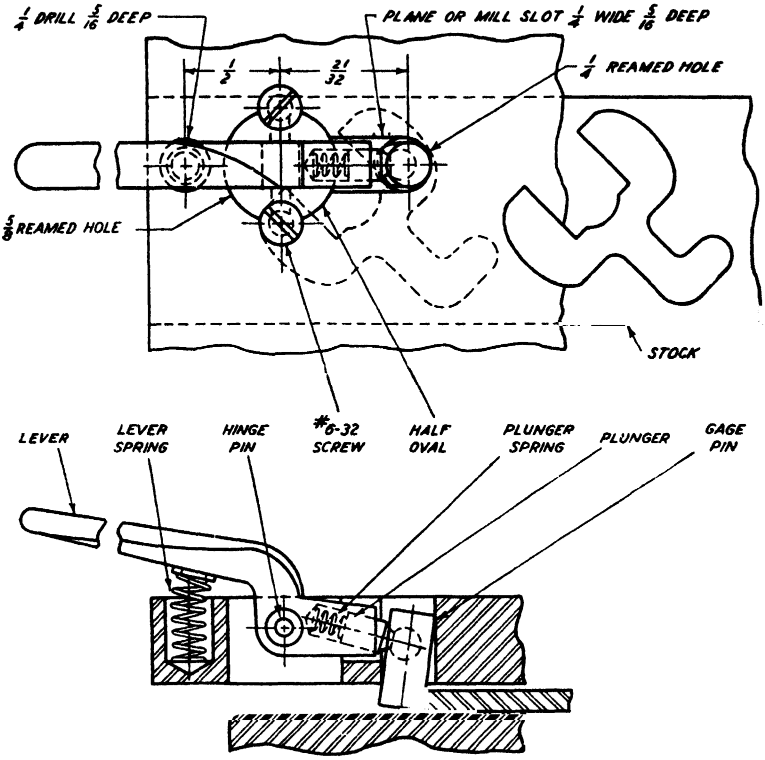


Fig. 37. Automatic Stock Feed Stop
Courtesy of Danly Machine Specialties, Inc., Chicago, Ill.

In the illustration it will be noted that the operator feeds the *stock against the gage pin, which has considerable play in the hole in which it is located. The set screw in the punch holder strikes* the lever, lifting the gage pin so that it clears the stock. This pin lies on top of the stock during the down stroke of the press. As the punch shears from the stock on the upstroke, the stock is free to be fed forward, the gage pin drops back into the hole that has just been blanked, and the stock will come to a stop as it was in the original position. With one of these automatic stops on a die, it is only necessary for the operator to feed the stock forward with a steady pressure.

Other forms of stops are designed and used for dies. These are illustrated in the section of this book on die design.

There are a number of standard products which cannot be illustrated or described in a book of this kind due to space limitations. The items in the preceding pages are to serve as a guide for the student tool designer so that he can incorporate some of the various standard items in the tools he will be called upon to design. As previously mentioned, a complete file of manufacturers' catalogs will also greatly assist the tool designer in his job. All this will be the means of enabling him to produce better and cheaper tools, to say nothing of the time saved in designing.

A study of trade magazines is one very good way for the tool designer to keep up to date; not only should the various articles in these trade magazines be read, but a careful analysis should be made of the advertising pages, which are a constant source of information. By investigating the new items that are being put on the market by reputable manufacturers, and in some cases trying to use these new items in the tools he is designing, the tool designer can increase his knowledge of tools and improve his position. The employee who has initiative and ability is seldom unemployed. The tool designer who keeps his mind open to new ideas and is willing to progress has every opportunity to advance in his chosen work.

QUIZ QUESTIONS

1. Name some of the first types of standard tools that were produced by commercial concerns for the convenience of the tool industry.

2. Name the six types of commercial drill bushings.

3. On what types of jobs are commercial clamp locks used?

4. On what type of job are slip renewable bushings used?

5. In selecting clamps for a job, what two considerations should the designer keep in mind?

6. On what type of production job is a clamp using a roller type cam used?

7. When the clamping operation is held to a minimum height, what are some of the special features that are developed in the design of clamps?

8. On what type of work are swinging clamps used?

9. What are some of the advantages of using a commercial type of rack and pinion jig?

10. On what types of work are automatic locks used?

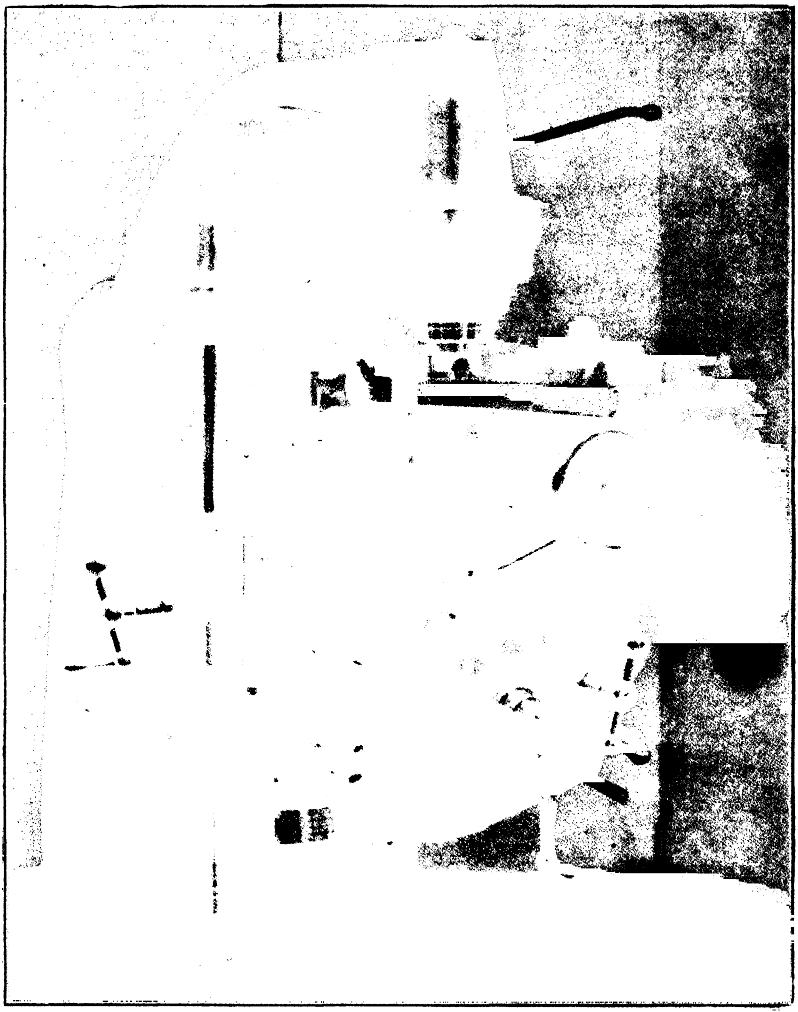
11. What is the advantage of using index tables on certain types of work?

12. When ordering a commercial die set, what are the essential specifications the tool designer must make?

13. When dowel pins were made in the average tool room, what were some of the difficulties this type of pin caused?

14. On what type of work are automatic stock feed stops used?

15. How can the tool designer keep up to date in the development of his work?



VERTICAL MILLING MACHINE WITH PROFILE MILLING FIXTURE MOUNTED ON THE TABLE

Courtesy of Cincinnati Milling Machinery Co., Cincinnati, Ohio

CUTTING TOOLS

At the present time the designing of metal cutting tools offers many problems to the tool designer, due to the wide variety of metals in general use in metalworking plants. Therefore, numerous factors must be given careful consideration before cutting tools can be designed. Among these factors are: the part to be machined, the material to be used, the number required, and the type and size of machine tool to be used for machining the part

After the tool designer has learned these facts, it is necessary for him to decide what type of cutting tool he should design and what material should be used in the tool. For example, if the piece part is to be machined in a drill press, the tool designer chooses the type of cutting tool on the basis of the material from which the piece part is to be made, and on the machining operations that will be necessary to produce the part. If the part is to be made from cast iron, the cutting tool can be made of high-speed steel; or if the quantity of parts to be produced is large, the cutting tool may be made with a tungsten carbide tip in order to machine these parts economically. However, this does not apply in all cases because, if a casting is used, bad scale condition in the piece part might make it necessary on low-production jobs to choose tools tipped with tungsten carbide. It might also be the case that the piece part would be designed so that an intermittent cut would be required. This means that there would be openings in the bore, and of course the cutting tool would not be in contact with metal at these openings. A condition of this kind often prevents the use of tungsten carbide, as it does not stand shocks as well as high-speed steel.

The tool designer therefore must exercise good judgment in the selection of materials for the cutting tools. Consulting the foreman of the department where the part is to be machined will often help the tool designer to specify the correct material for the cutting tools. A study of tool manufacturers' catalogs, and personal observation of cutting tools at work in the plant, will be of great assistance to the tool designer and add to the knowledge and experience so necessary if he is to design cutting tools.

There are a large number of manufacturers of cutting tools whose products are in wide use in metal-manufacturing plants. These specialists are in most instances able to furnish better and cheaper tools than can be designed or built in the average metal-working plant. However, in many instances it becomes necessary to make a special cutting tool in order to accomplish some particular operation. Therefore, it is well for the tool designer to have a thorough knowledge of available standard tools. The study of catalogs that show cutting tools will help the designer to know what is available and enable him to design special cutting tools which will obtain the best results for the job in question.

Due to the development of machine tools, requirements for new types of cutting tools are almost unlimited in the metalworking industry. It is therefore impossible to cover the entire range of cutting tools in a book of this kind, and no attempt will be made to describe and illustrate the entire range.

BROACHES

In modern production the use of broaches is constantly increasing by reason of the fact that broaching is the most efficient and economical way of machining certain parts; for example, a splined bore of a gear. If broaches were not available, the cost of putting splines in the bore of a gear would almost be prohibitive. The automotive and tractor industries have been largely responsible for the increased use of broaches at the present time. Many parts formerly machined by the use of milling machines and milling cutters are now done by broaching, as this latter method has proved faster, cheaper, and more accurate for machining certain types of jobs.

Broaches are different from many other cutting tools in that the accuracy that is put in the broach will reproduce itself in or on the part to be machined. This is not true of most other types of cutting tools.

There are two classes of broaching; namely, internal and external. The broaching process was originally developed for internal use; that is, for changing the round hole in a piece of metal to a square hole or to some other shape, also for internal keyways in pulleys, gears and couplings. Through a process of development broaches were designed for cutting internal gears, multiple splines, and for various other irregular shapes. There are two types of internal broaches now being used; they are *pull broaches* and *push broaches.*

Hydraulic Broaches. Fig. 1 illustrates a hydraulic broaching machine with a fixture attached. These fixtures are removable, in fact a great many broaching operations can be performed without the use of fixtures. This machine is designed for the use of pull broaches.

Fig. 1. Hydraulic Horizontal Broaching Machine Showing Removable Fixture Attached
Courtesy of Colonial Broach Company, Detroit, Michigan

The process of broaching consists of pulling or pushing a broaching bar through a piece of work by means of a power-driven horizontal or vertical broaching machine. In some cases a push broach can be used in a punch press. These broaches are considerably shorter than pull broaches and in many cases several push broaches are required to perform the operation that can be done with one pass of a pull broach; therefore pull broaches are used in the majority of high-production plants.

Fig. 2 illustrates a double-spindle vertical hydraulic broaching machine. This machine is equipped with fixtures for broaching automobile connecting rods and bearing caps. Pull broaches are used, but instead of pulling the broaches horizontally they are *drawn up past the work, completing the operation at each stroke.*

The broaching bar or broach, as it is commonly called, is generally made of high-speed steel machined to the desired shape and approximate size, allowance being made for grinding. After this it is hardened and drawn, then carefully ground to the required finished dimensions.

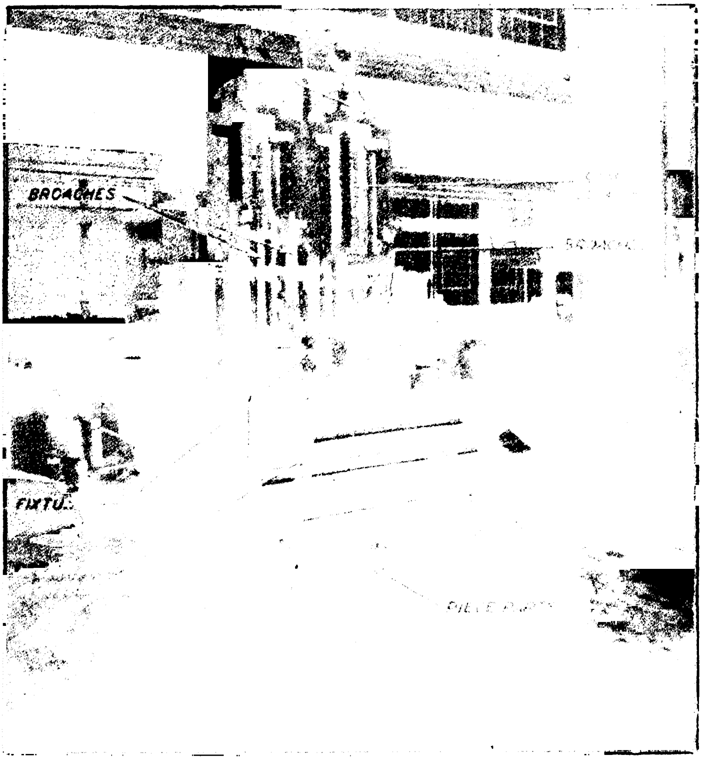


Fig. 2. Double-Spindle Vertical Hydraulic Broaching Machine
Courtesy of Colonial Broach Company, Detroit, Michigan

Keyway Broaches. These broaches, Fig. 3, are probably the most generally used. In designing keyway broaches the length of work must be taken into consideration, also the material to be cut. This type of broach is used with a round, threaded adapter into which the broach is screwed. The adapter has an elongated slot so that it can be attached to the draw head of a broaching machine *by means of a flat key. This permits rapid removal of the broach from the work after the keyway has been machined.*

Fig. 4 shows general information for designing keyway broaches. As already stated, the length of the work is very important because it determines the pitch of the broach teeth or the distance from one cutting tooth to the other. The amount of material to be removed by the broach determines the cut per tooth; this is also a variable factor, as the type of material being broached often determines the amount of cut per tooth. The angle to which the broach tooth is ground also depends on the type of material to be broached.

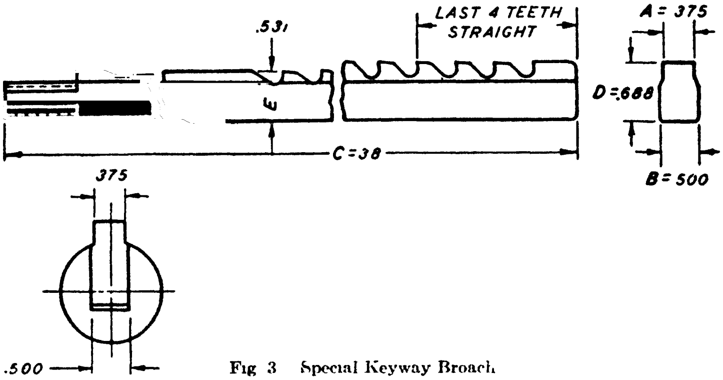
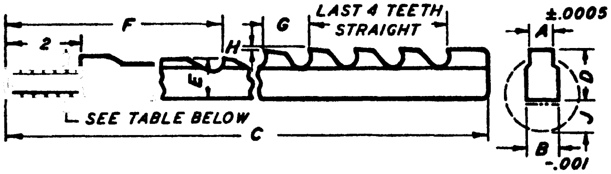


Fig 3 Special Keyway Broach

Miscellaneous Broaches. Some of the various shapes of broaches are illustrated by Fig. 5. This table gives some of the lengths in which the keyway broaches are regularly furnished and, as it is becoming common practice for a great many plants using broaches to design their own tools, a table of this kind will assist the tool designer to design broaches to the best advantage from the standpoint of cost. Certain diameters, widths, and lengths have been used for the basis for the design of the broaches, and these are shown in this table.

The important thing for the tool designer to remember in designing broaches is that if the number of parts to be produced is large, it is well to specify this on his tool drawing so that the plant may order the entire number of broaches at one time, as the price of broaches is based on the quantity ordered; for example, the following are price groups, 1 to 2, 3 to 5, 6 to 11, 12 to 23. In other

Keyway Broaches — General Information



A = The mean of the width of keyway

B = Lowest limit of slot in fixture—0.001

$$C=F+4G+\left(\frac{D-E}{H}G\right)$$

D = Height of keyway—J

$E=D-(J+x)-.015$ or $\sqrt{r^2-\frac{A^2}{2}}+(D-r)-.015$ (Take x from Sheet No.)

F = Length of fixture + 5. Usually 10 inches = F

G = See table below

H = See table below

J = Taken from fixture

Number of Teeth Cutting at Once

Usually not less than 3; 6 or 7 is maximum.

Work Length, In.	Dim. G, In.
½ to 1	3/16 to 5/16
1 to 1½	5/16 to 3/8
1½ to 2	3/8 to 7/16
2 to 2½	½ to 9/16
2½ to 3	5/8 to 11/16
3 to 3½	¾ to 13/16
3½ to 4	13/16 to 7/8
4 to 5	7/8 to 15/16
5 to 6	15/16 to 1

Cut per Tooth = H

Round broaches, .002 on diameter

Spline broaches, .004 to .005 on diameter

Keyway broaches, .0035 to .006, depending on work material

Broach Data

Material: high-speed steel preferred

Stamp: Part No., Dept. No., Dwg. No.

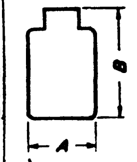
Give Dim. *A*, *B*, *C*, *D*, & *E* on order dwg.; Dim. *A*, *B*, *D*, & *E* in decimals.

Width A	¼	5/16	3/8	½	5/8
Thread	½-13 N.C. 2	5/8-11 N.C. 2	5/8-11 N.C. 2	¾-10 N.C. 2	1-8 N.C. 2

Fig. 4

words, 1 or 2 broaches are sold at a higher rate than 3 to 5 would be, etc. In the event a plant would use six broaches a year for a

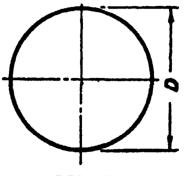
Data on Broaches



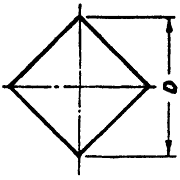
Lengths, In., Used in Computing Keyway and Flat Broaches	Diameters, In., Used in Computing Round, Spline, Square, Hexagon, Octagon and Oval Broaches	Width A	Height B
4	.250-.390	.265	.515
5	.515	.390	.640
6	.640	.515	.765
7	.765	.640	.890
8	.890	.765	1.015
9	1.015	.890	1.140
10	1.140	1.015	1.265
11	1.265	1.140	1.390
12	1.390	1.265	1.515
13	1.515	1.390	1.640
14	1.640	1.515	1.765
15	1.765	1.640	1.890
16	1.890	1.765	2.015
17	2.015	1.890	
18	2.140	2.015	
19	2.265		
20	2.390		
22	2.515		
24	2.640		
26	2.765		
28	2.890		
30	3.015		
33			
36			
39			
42			
45			
48			
51			

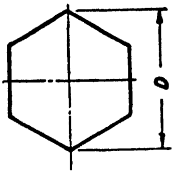
NOTE.—Round, spline, square, hexagon, octagon, serration and oval broaches are priced in inch lengths. Minimum length used is 6". Fractional lengths are based on next full inch. For instance, a round broach 19¼" long is priced as 20" long.

Dimensions shown on sketches below used to determine diameters of stock. Must be figured at finish end of broach only.

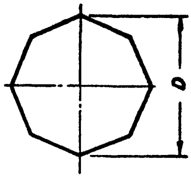


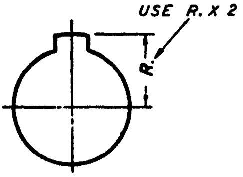
Use distance across corners at all times for square broaches whether the corners be sharp or round.



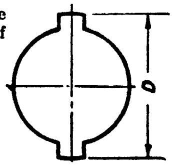


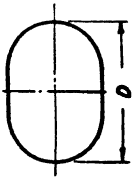
Above note applies also to hexagon and octagon broaches; also, serration broaches.

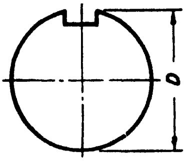




Use outside diameter of all spline broaches with the exception of the one spline.







Use outside diameter of all inverted spline broaches.

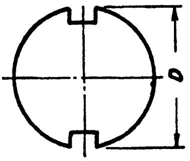


Fig. 5

certain job, it would be cheaper to buy these six at one time rather than place two orders for three each, as the larger order would result in a considerable saving.

The designing of spline broaches is somewhat complicated and most metalworking plants rely on the manufacturers of broaching *bars to furnish the correct design of spline broach for the work they want machined. This is also true of external broaches. Some* of these are made of solid high-speed steel, while others are made with inserted teeth similar to inserted-tooth milling cutters. Therefore, no attempt will be made in this book to illustrate and describe various types of spline and external broaches.

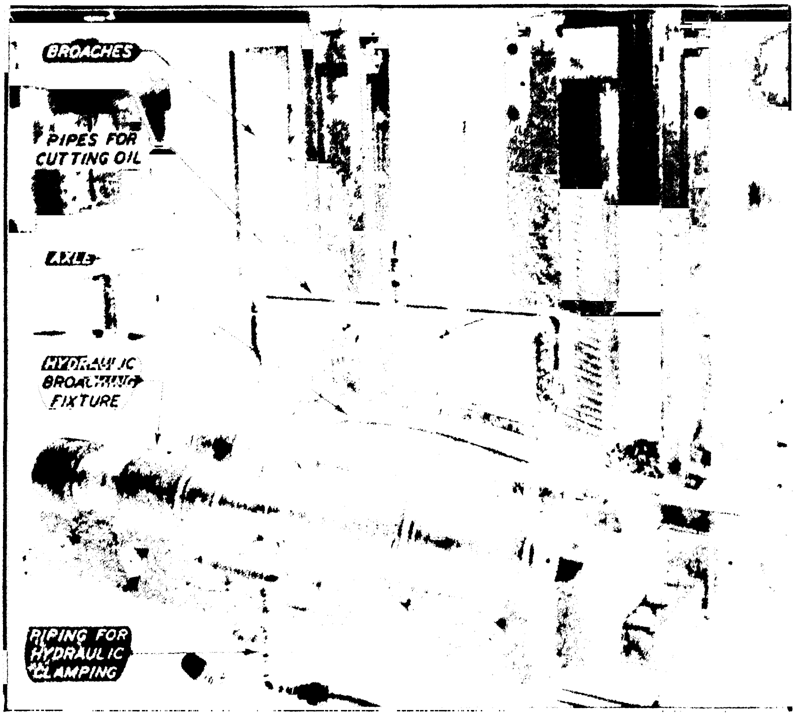


Fig 6 External Broaching Operation on an Automobile Axle
Courtesy of Colonial Broach Company, Detroit Michigan

Fig 6 illustrates an external broaching operation on an automobile axle. It will be noted that both ends of this axle are being machined simultaneously. The parts are clamped by means of a hydraulic broaching fixture which automatically clamps the work for the broaching operation.

External broaching has replaced milling operations on a great many jobs in the automotive industry. The main bearing bores of cylinder blocks are now machined by the use of special continuous *broaching machines which are designed so that broach sections are mounted on a continuous steel chain or belt similar to a conveyor* These parts are fed into the machine and the broaches rapidly machine in the sections desired. This is one reason why a great many manufacturers of milling machines and milling cutters are now manufacturing broaching machines and broaches.

BORING CUTTING TOOLS

Boring is probably one of the oldest principles of machine shop practice. In the early days of the metalworking industry it was common practice to make parts out of cast iron and core a great many of the holes that had to be machined. This was because drilling was usually a slow operation up until the time the two-flute twist drill was invented. The first boring tools consisted of a solid piece of tool steel with the front end bent over at an angle so as to permit clearance. They were usually made by the blacksmith and then the cutting edge was properly ground. These tools of course had their limitations, as only short lengths of work could be machined. Then it was found that an ordinary round piece of steel could have a square or round slot put into it, a piece of tool steel could be inserted and held by means of a screw, and this would bore out to any depth required, depending on the length of the bar. This type of tool was known as a single-point boring bar.

In designing boring bars there are numerous factors that must be given careful consideration by the tool designer. These points are common to most types of boring bars; therefore, the designing of cutting tools used in conjunction with boring bars will be discussed separately.

The boring bar should be designed and constructed so as to be as rigid as possible; that is, the bar should be of sufficient diameter to overcome any tendency to spring away from the work when a cut is being taken. In some cases this rigidity can be secured by specifying a carburized and hardened boring bar, as this type is more rigid than a soft one. Boring bars should have pilots whenever conditions permit. Some work requires more than one pilot, in which case pilots are put on both front and rear; these to be as large in diameter as the design of the job will permit. The pilots also must be of sufficient length to guide the boring bar for the entire length of cut, and should enter the guide bushings a reasonable distance before the cutting tools begin to operate.

The most accurate boring is done by means of a boring fixture that has pilot or guide bushings on each end. These bushings must be long enough to guide the boring bar properly. It is considered good practice to design these bushings so that their length is one and one-half to two times the diameter of the boring bar. For example, if the diameter of the pilot sections of a boring bar is 4″, the pilot bushings should be 6″ to 8″ long.

In using a fixture of this type the work to be bored is located and clamped in the fixture and the piloted boring bar is then inserted in the bushings through the fixture. The machine tool that is to drive the boring bar has a floating chuck attached to the spindle to fit the shank end of the boring bar. This permits the boring bar to be independent of any misalignment between the machine tool spindle and the table. The guiding is all done by the pilot bushings in the fixture by means of a floating chuck driver between the machine tool spindle and the boring bar. The degree of accuracy that is designed and built into the boring fixture and boring bars will be reproduced in the work. In many cases boring bars can only be piloted on the front end. These pilots should be long enough to enter the guide bushing before the cutting tools start to operate, and should be of sufficient diameter to prevent any springing.

It is desirable to harden the pilots of boring bars. In some instances this is not practical, and in this case pilots are equipped with wear strips of hardened and ground tool steel. Usually four strips are used that are attached to these pilots by means of screws. In other designs it is possible to provide hardened wearing surfaces on pilots of boring bars by means of welding, usually Stellite. This metal is put on the pilot of a boring bar by means of an acetylene torch and is then ground to the required diameter.

Material for Boring Bars. The tool designer chooses the material for the boring bars, taking into consideration the job on which the boring bars are to be used, the amount of material to be removed from the work, the number of pieces to be made, and the design of the work itself.

There are three general classifications of material for boring bars as follows: soft, heat treated, and carburized and hardened steel. These steels are alloys and have the following characteristics.

1. Soft Steel. This is high manganese chrome steel annealed to relieve all strains. It is used on unpiloted bars where the cutting load is not too heavy, and upon bars with pilots where the production quantities are not large. When fixtures are designed for use with a bar of this type, or where it is used in conjunction with the horizontal boring mill, the pilot bushings should be made of bronze or cast iron.

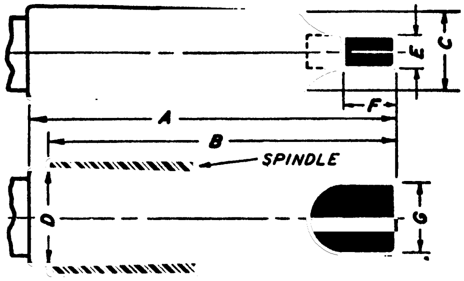
2. Heat Treated. (a) Bars designed to be heat treated are usually made of .40% carbon high manganese chrome alloy steel, but not hardened. This heat treatment consists of heating to the required temperature and then quenching; the resulting hardness is approximately 29° to 31° Rockwell C. A steel of this type is used where the cutting load is somewhat greater than a soft bar could handle. A heat-treated bar resists wear over a longer period and the pilot bushings should be made of bronze or cast iron.

(b) .50% carbon high manganese chrome alloy steel, heat treated but not hardened, gives a very desirable boring bar. This steel is of denser structure and is used for boring bars when the cutting conditions are severe. The physical properties are high and bars made from it can be subjected to heavy loads and severe torsional strains; it also withstands sudden shocks very well. The pilot bushings for use with a bar of this type should also be made of bronze or cast iron.

3. Carburized and Hardened. Bars that are to be hardened and ground are made of low-carbon high manganese chrome alloy steel. The low carbon content permits this steel to absorb a dense layer of carbon on the surface. This results in a hard, uniform outer case, together with a tough fine-grained core to stand cutting shocks, and also provides a bar with considerable rigidity. One of the outstanding advantages of a carburized and hardened bar is that this method of heat treatment permits sections, where the cutting tools are to be inserted, to be left soft so that after the bar has been carburized these sections can be machined to remove the carbon. The bar is then heated again to the required temperature and quenched. Pilot bushings used in conjunction with bars of this type are made of steel and hardened to resist wear.

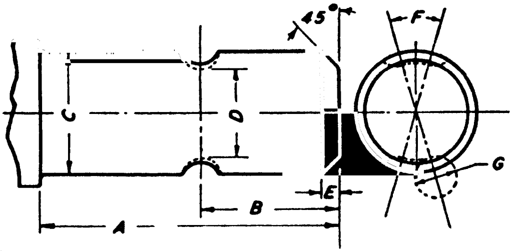
Standard Shanks for Boring Bars

Morse Taper — Dimensions in Inches



No.	A	B	C	D	E	F	G	Taper per Foot
0	2 11/32	2 7/32	.240	.356	5/32	1/4	.235	.625
1	2 9/16	2 7/16	.353	.475	13/64	3/8	.343	.600
2	3 1/8	2 15/16	.5525	.700	1/4	7/16	17/32	.602
3	3 7/8	3 11/16	.753	.938	5/16	9/16	23/32	.602
4	4 7/8	4 5/8	.991	1.231	15/32	5/8	31/32	.623
5	6 1/8	5 7/8	1.4395	1.748	5/8	3/4	1 13/32	.630
6	8 9/16	8 1/4	2.0635	2.494	3/4	1 1/8	2	.626
7	11 5/8	11 1/4	2.6841	3.270	1 1/8	1 3/8	2 5/8	.625

Magic Chuck — Dimensions in Inches



No.	A	B	C	D	E	F	G
0	2 1/4	3/4	.6868	.524	1/16	32°	.234
1	2 5/8	1	.9365	.748	5/64	32°	.327
2	3 1/2	1.240	1.2485	.926	5/64	32°	.4525
3	4	1 9/16	1.686	1.355	3/32	32°	.4525
4	4 3/4	1 13/16	2.373	1.988	1/8	32°	.515
5	6	2 1/2	3 1/4	2 13/16	5/32	1" C. to C.	.625

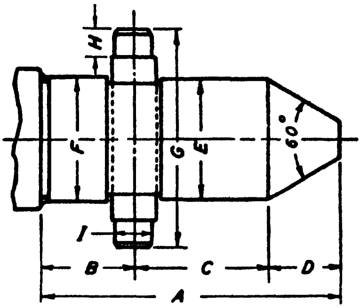
Fig. 7A

Shanks for Boring Bars. The design of the shank end of boring bars is often a matter of individual choice, depending on the machine tool in which the bars are to be used. Most bars are designed with Morse taper shanks, although many are designed for use with various types of rapid-change chucks. A table of standard shanks for boring bars is shown by Figs. 7*A* and 7*B*.

Many individual plants have their own design of shanks for boring bars. Some consist of a pin of sufficient diameter to drive

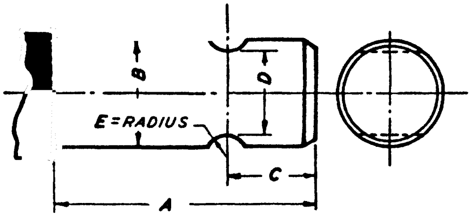
Standard Shanks for Boring Bars

Wizard Chuck — Dimensions in Inches



No.	A	B	C	D	E	F	G	H	I
A	3 5/16	13/16	1 13/16	11/16	29/32	.936	1 3/4	7/32	5/16
B	3 15/16	15/16	2 17/64	47/64	1 7/32	1.249	2 1/4	9/32	3/8
C	4 3/8	1 7/32	2 3/64	1 7/64	1 21/32	1.686	2 27/32	5/16	9/16
D	6 9/16	1 15/32	3 15/32	1 5/8	2 11/32	2.374	4 1/16	5/16	11/16

Rapid Slip Chuck — Dimensions in Inches



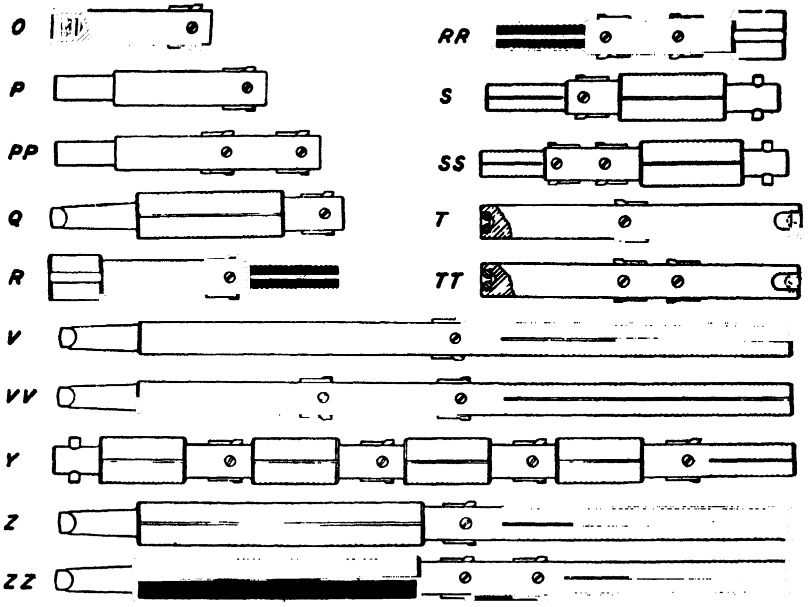
Collet No.	A	B*	C	D	E
0	2 1/4	.685	3/4	.500	3/16
1	2 1/4	.935	1	.715	5/16
2	3 1/4	1.248	1 1/4	.940	3/8
3	3 3/4	1 685	1 9/16	1.310	3/8
4	3 3/4	2.373	1 13/16	2.020	3/8

Fig. 7B

the bar and are used in conjunction with a bayonet type chuck or driving mechanism. Others have a flat milled on the shank end of the bar and a simple chuck with two hollow-head setscrews set in the chuck at right angles to the shank.

Designs for Boring Bars. There are various designs for boring bars and the tool designer must consider all the factors concerning the job before beginning the design. The length of the work, the amount of travel in the cut, the decision as to whether or not a fixture is to be used, determine the design of the boring bar. Fig. 8 illustrates some of these designs. In this illustration, bars are shown with and without pilots and with various types of shanks.

Boring Bar Designs

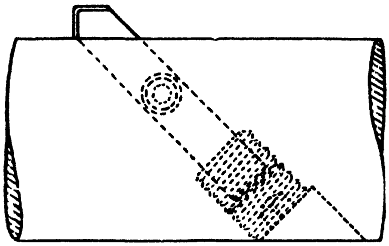


Description of Standard Designs

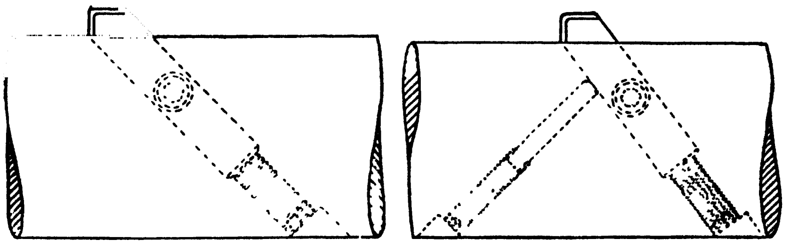
O	Short stub bar with threaded socket to be used as an extension to the spindle or bar. Used principally for miscellaneous work.
P and PP	Unpiloted stub bar with one or more cutting units for use on engine lathes, turret lathes and drill presses.
Q	End bar with rear pilot only. Generally used upon work which is fixtured to provide for rear pilot. Although shown with one cutting unit only, it may be provided with more for multiple cutting.
R and RR	Front piloted bar with one or more cutting units. Used upon turret lathes and drill presses as a rule, but also upon fixtured work.
S and SS	Front and rear piloted bar to be used with fixtures which provide proper bearing locations.
T and TT	Engine lathe bar to be used between centers. Furnished with one or more cutting units.
V and VV	Front piloted bar for boring mill work to mount in the spindle of the machine and pilot in the outboard bearing. Can be furnished with any number or location of cutting units.
Y	Multiple cutting line bar for fixtured work where a number of cuts are to be taken simultaneously and a number of bearing supports are provided.
Z and ZZ	Front and rear piloted bar for long work principally upon boring mills, although extensively used for cylinder boring and reaming.

Fig. 8

In some instances it will be noted that bars are piloted front and rear, and in other types of bars it will be seen that there are two or more pilot sections on the bar as well as a multiplicity of cutting tools. In some instances bars are designed so that a cut is taken on the forward traverse of a boring machine spindle. After this section has been machined in the work, the tools are inserted in the forward end of the boring bar and a draw cut is taken on the reverse stroke of the boring machine spindle. There is no particular design of boring bar that will be suitable for all jobs; however, there are in some cases two or more designs equally good.



A. Open End Type



B Closed End Type

C. Closed End Supported Type

Fig. 9 Single-Point Boring Bars

Single-Point Boring Bars. Fig. 9 illustrates various means for inserting the single-point tools into boring bars. They are still widely used on miscellaneous work for small production runs where the expense for other types of boring bars would be too great for the job in question. They are also used on production jobs where crowded cutting conditions and lack of clearance exist.

In the open-end type of single-point boring bar shown in Fig. 9 at (*A*) the square hole is broached through the bar; it is either perpendicular to the axis or on an angle. The square hole is then *counterbored at the rear end and threaded so that a heavy adjusting* screw will back up the square tool bit, and a binding screw is placed at the side to lock the tool bit in position. These square holes should be broached to a standard size so as to permit the use of standard tool bits, these sizes being shown in the tool steel manufacturer's catalog. This is the simplest design of single-point boring tool.

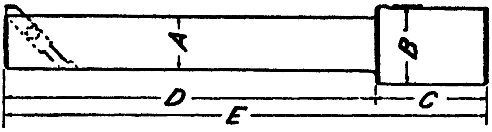
The closed-end type of single-point boring tool, shown in Fig. 9 at (*B*) offers greater rigidity because the hole is broached only part way through the boring bar, then a smaller hole is drilled and tapped for the adjusting screw. This means that adjustment can be obtained on the square cutting tool bit and the tool bit is backed up very solidly. A design of this type is used frequently where a number of tool bits are required in the boring bar.

Where the tool designer is confronted with conditions that are unusually severe for single-point boring bars of other types, a closed end supported type is desirable. This design, shown in Fig. 9 at (*C*), is similar to the closed-end type shown at (*B*) except that a binding screw is put into the boring bar at right angles to the square tool bit. This is in addition to the binding screw that is used in the other two types. In every instance it is desirable to use socket-head setscrews for adjusting single-point boring tools, as these screws do not project beyond the diameter of the bar and therefore do not cause any interference with parts of the machine or the work; and their use removes the danger of screws being broken off in handling the bars.

Single-point boring bars are used to a considerable extent in engine lathes and turret lathes, also in single-spindle drill presses, radial drill presses, and in horizontal and vertical boring mills. Fig. 10 illustrates the design and gives sizes of some of these single-point boring bars.

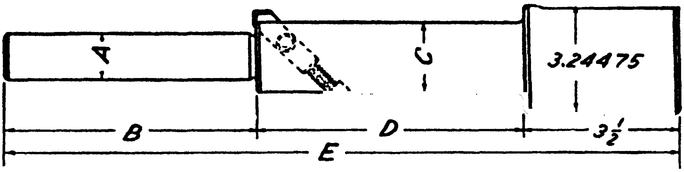
A type of boring bar frequently used in turret lathes is shown in Fig. 11. It will be noted that this roughing boring bar at (*A*) is designed with a pilot on the front, which operates in a bushing in the turret lathe spindle. This bar has two inserted square tool bits, and in addition a flat high-speed steel blade is inserted near the shank end as a counterboring tool. Almost unlimited combinations of this type of tool can be designed and used for production jobs.

Single-Point Stub Bars



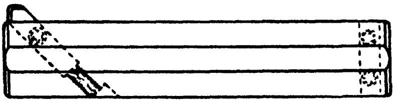
Body *A* Dia., In.	Shank *B* Dia., In.	Shank *C* Lgth., In.	Body *D* Lgth., In.	Over-all *E* Lgth., In.	Size of *F* Tool Bit	Range of Bore, In.
13/16	1 1/4	3	5 1/2	8 1/2	1/4" Sq.	7/8 to 1 1/8
1	1 1/4	3	7 1/2	10 1/2	1/4" Sq.	1 1/8 to 1 3/8
1 1/4	1 1/2	4	8 1/2	12 1/2	5/16" Sq.	1 3/8 to 1 5/8
1 1/2	1 1/2	4	8 1/2	12 1/2	3/8" Sq.	1 5/8 to 2
1 3/4	1 1/2	4	8 1/2	12 1/2	3/8" Sq.	2 to 2 1/4
2	1 3/4	4	8 1/2	12 1/2	1/2" Sq.	2 1/4 to 2 5/8
2 3/8	1 3/4	4	8 1/2	12 1/2	1/2" Sq.	2 5/8 to 3
2 1/2	2	4	8 1/2	12 1/2	5/8" Sq.	3 to 3 3/4
3 1/2	2	4	8 1/2	12 1/2	5/8" Sq.	3 3/4 to 4 1/2

Single-Point Piloted Bars



Pilot *A* Dia., In.	Pilot *B* Lgth., In.	Body *C* Dia., In.	Body *D* Lgth., In.	Over-all *E* Lgth., In.	Tool Bit *F* Size	Range of Bore, In.
1 3/8	15	1 3/4	11 1/2	30	1/2" Sq.	2 to 2 3/4
2	15	2 3/8	11 1/2	30	5/8" Sq.	2 5/8 to 3 3/8
2 3/4	15	3 1/8	11 1/2	30	5/8" Sq.	3 3/8 to 4 3/8
3	15	3 7/8	11 1/2	30	7/8" Sq.	4 3/8 to 6
3	17	5	15 1/2	36	1" Sq.	5 3/4 to 7 3/4
3	17	6 1/8	15 1/2	36	1" Sq.	7 to 9
3	20	8	18 1/2	42	1 1/4" Sq.	9 to 12

Single-Point Cross-Slide Bars



Bar Dia., In.	Bar Length, In.	Size of Tool Bit	Bar Dia., In.	Bar Length, In.	Size of Tool Bit
1	18	5/16" Sq.	2 1/4	18	1/2" Sq.
1 1/4	18	5/16" Sq.	2 1/2	18	1/2" Sq.
1 1/2	18	3/8" Sq.	2 3/4	18	5/8" Sq.
1 3/4	18	3/8" Sq.	3	18	5/8" Sq.
2	18	1/2" Sq.	.	. .	. . .

Fig. 10

The finishing boring bar shown in Fig. 11 at (*B*) also has two inserted square tool bits. The purpose of these two tool bits is to maintain size. Most of the cut is taken by the first bit, the second tool bit taking up any inaccuracies that would be produced by

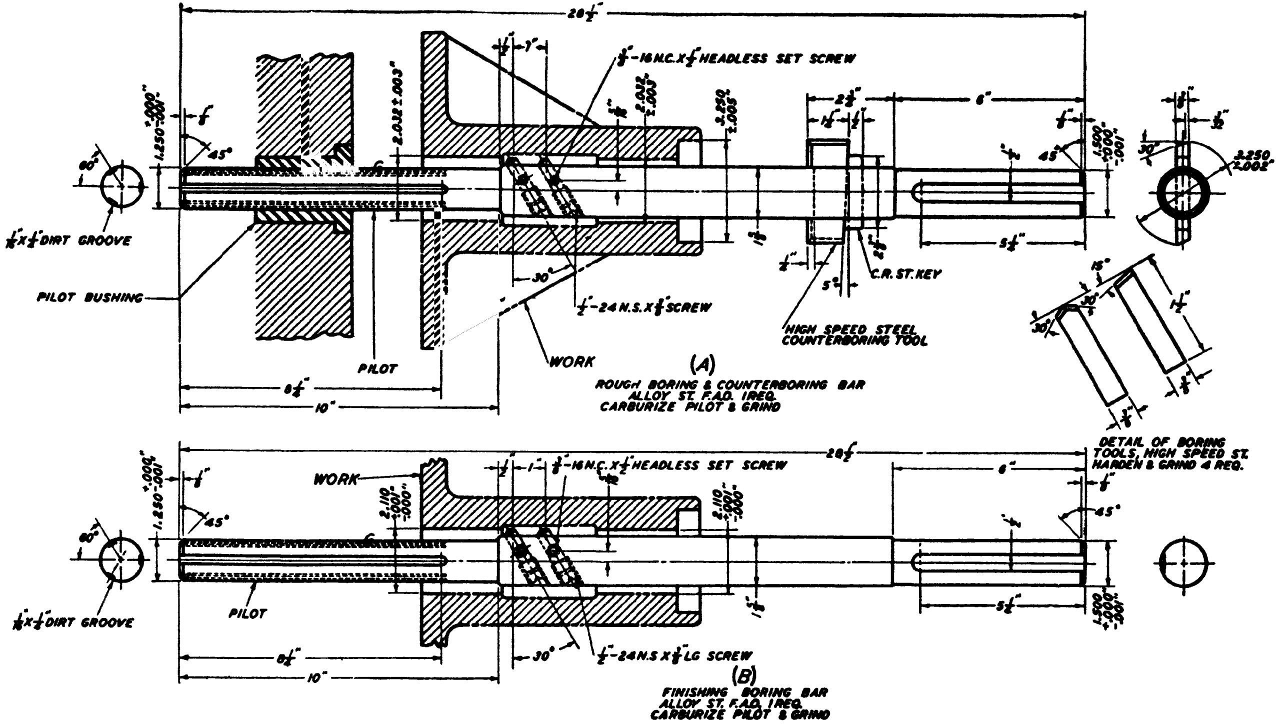


Fig. 11. (*A*) Boring Bar for Rough Boring and Counterboring a Cast-Iron Stand; (*B*) Boring Bar for Finish Boring a Cast-Iron Stand

springing of the bar. This prevents frequent regrinding of the tool bits.

Fig. 12 shows a different type of single-point boring bar with five square tool bits, together with a chamfering head with an inserted blade for facing. These blades are made of flat high-speed steel and are held in the head by means of hollow-head setscrews. This is one of the numerous combinations of single-point boring bars

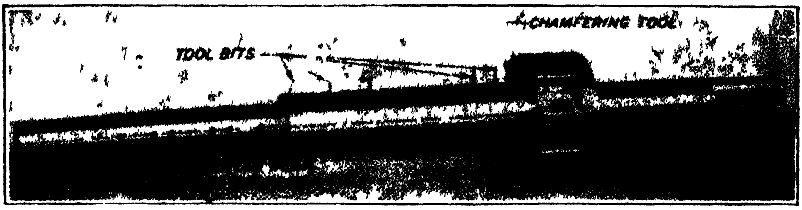


Fig 12 Single-Point Boring Bar

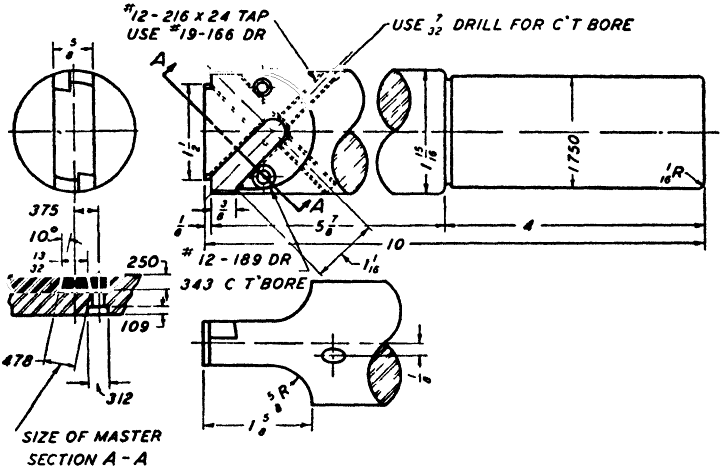


Fig 13 Rigid Type Boring Bar

Fig. 13 illustrates a rigid type boring bar with the cutting tools inserted in a dovetail slot. This design of bar is excellent for roughing operations, due to the large amount of clearance that is provided for chips. This bar is very strong because there is no slot entirely through the bar to weaken its cross section

Combination Bars. Fig. 14 illustrates a combination boring, counterboring, facing, and chamfering bar using the design of tool bit shown in Fig. 13.

Boring Bars with Inserted Blades. On some jobs where extreme accuracy is necessary, it is desirable to provide roughing and finishing bars. Fig. 15*A* is a roughing bar designed to rough three diameters in a piece of work. The construction is of the inserted blade type with hardened and ground tool steel stripped pilots. This bar is designed for use in a turret lathe. The bar in Fig. 15*B* has removable block type cutters that are designed to float in the bar. The use of a bar of this type, where the boring cutters float, eliminates any inaccuracies produced by the roughing boring bar and leaves a finely finished and accurate bore.

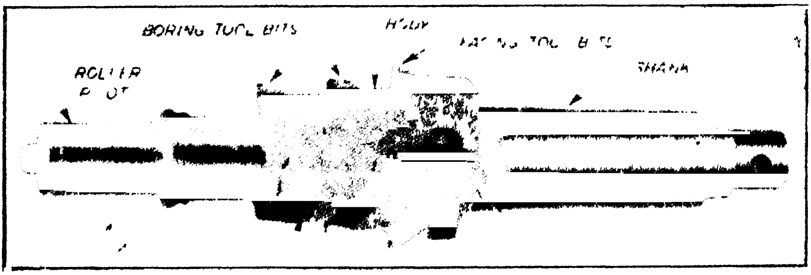


Fig 14 Combination Boring, Counterboring, Facing and Chamfering Bar

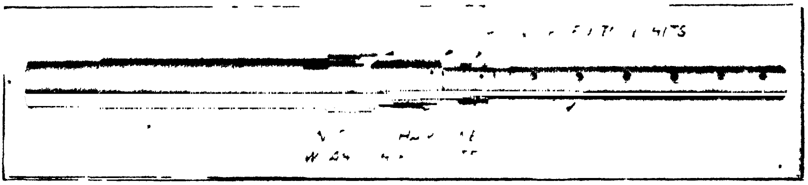


Fig 15A Roughing Bar Designed to Rough Three Diameters in a Piece Part

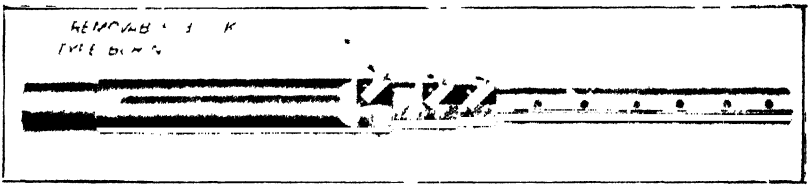


Fig 15B Boring Bar with Removable Block-Type Cutters

In some types of internal-combustion engines where an inserted cylinder sleeve is used, the bores in the crankcases to receive these sleeves are necessarily machined very accurately, as the sleeve fit determines not only the accurate alignment of the pistons in connection with the crankshaft, but the fit must be so that it forms a water-tight seal to provide a water jacket for the cylinders.

Figs. 16*A* and 16*B* illustrate a bar designed for a job of this kind. Note that the pilot section has a key insert. This key acts as a driving member for a revolving bushing which is equipped with ball bearings to reduce friction and to maintain the required accuracy. The bar is equipped with a single-point square tool bit to perform the rough boring of both sections of this crankcase. Then there are special boring cutters that contain the cutting tool blades for semifinishing and finishing these bores. The final cutting tool is provided to counterbore for the seating of the cylinder sleeve. In addition to the revolving pilot bushing, this bar is also piloted in the rear by means of a pilot bushing. The shank is provided with a floating drive so that all inaccuracies between the spindle of the machine and the table are eliminated. Bars for jobs of this kind are used in multiples; in this instance four bars are used simultaneously in a four-spindle vertical boring machine. The bars themselves are carburized, hardened and ground. In a bar of this design it will be noted that the various tools are placed in the bar so that one tool is through the cut before the next tool begins to operate. In this way any possible chance of inaccuracy is eliminated.

It is always considered good practice to design boring tools so that one cutting tool is finished with the cut before the next tool comes into action, as two tools cutting simultaneously are liable to cause errors, particularly where there are two or more separate diameters. In some instances tool designers attempt to design tools so that a finish boring cut is being made while another tool is performing a counterboring or chamfering operation; usually the tool doing the finishing boring is affected and an unsatisfactory job is the result. However, on bores of large diameter it is sometimes possible to have a roughing tool cut ahead of a finishing tool, especially where the bar is of large diameter and is rigidly supported.

Reamer Bars. On some classes of work it is required that the roughing and semifinishing cuts be taken to obtain the desired

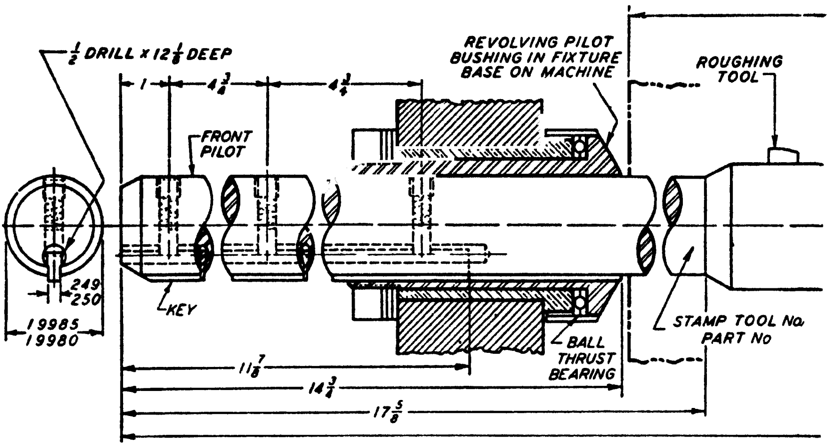


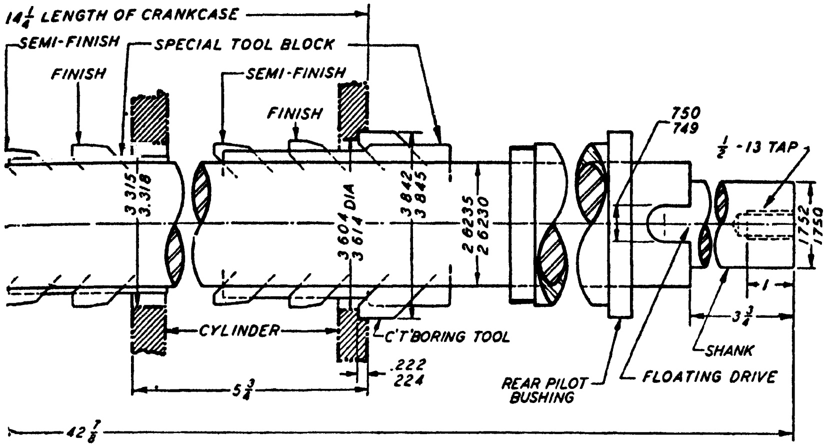
Fig 16A Left Half of Boring Bar Showing Front Pilot and Roughing Tool

dimension and leave a fine finish that will be accurate; for this work a reaming bar is usually designed.

When the term *reaming* is used, it implies that two or more cutting points will be in contact with the work being machined. It is always considered good practice to design reamers with at least six flutes or cutting edges Figs. 17*A* and 17*B* illustrate a reamer bar that is piloted on both ends. These pilots are the inserted strip type and are made from Stellite. This is a commercial standard and can be used in the regular lengths or cut off to suit the requirements of the individual job.

The front pilot is ground to a decimal dimension to insure positive alignment in the reaming fixture. The reamer portion of this bar is designed to be of the integral type; that is, the blades are attached directly to the bar by means of slots and wedges. The wedges have a taper on one side that matches the taper on the reamer blades. This taper is approximately 5°, which makes it a binding taper, as all angles or tapers of less than 15° are binding tapers. The wedges are attached to the bar by means of fillister-head screws.

It will be noted that the reamer blades, which are six in number, are to ream two diameters simultaneously. This has been made necessary by the design of the work. This piece part (work) shown



4-REQ CARB HDN AND GR

Fig. 16B. Right Half of Boring Bar Showing Cutting Tools and Rear Pilot

by Fig. 17*A* is a section of a transmission case, and the over-all length of the section to be machined is only $2\frac{9}{16}''$. Therefore it is difficult to design a reamer bar for this job in any other way, as the two holes must be in alignment and concentric with each other and it is necessary to obtain accurate decimal dimensions and a fine finish.

Reaming bars can also be designed for the use of inserted-blade shell reamers; however, on the particular job for which this reamer bar was designed, it was impossible to use the shell reamer type.

A reamer bar of the design shown in Figs 17*A* and 17*B* is an exception to the general rule, as it is not considered good practice to finish-machine two or more diameters at one time. As before stated, it is desirable wherever possible to finish-machine each diameter singly; however, where the design of the work does not permit this, it is often necessary to design a bar such as has just been described.

Boring Bars with Multiple Cutting Heads. Where it is necessary to produce items in very large quantities, special tooling is often designed to accomplish this purpose. Fig. 18 illustrates special multiple cutting heads. This bar of multiple cutting heads is used for boring, taper reaming, counterboring, and facing both ends of a standard pipe coupling prior to the tapping of the threads. These

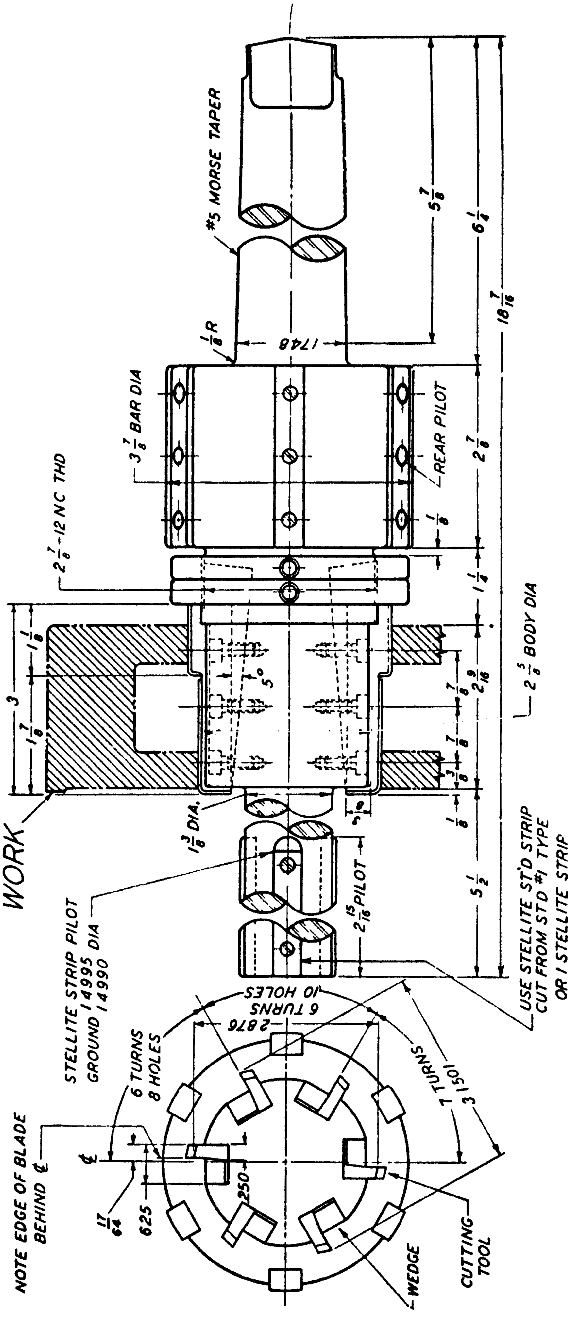


Fig. 17A. Reamer Bar

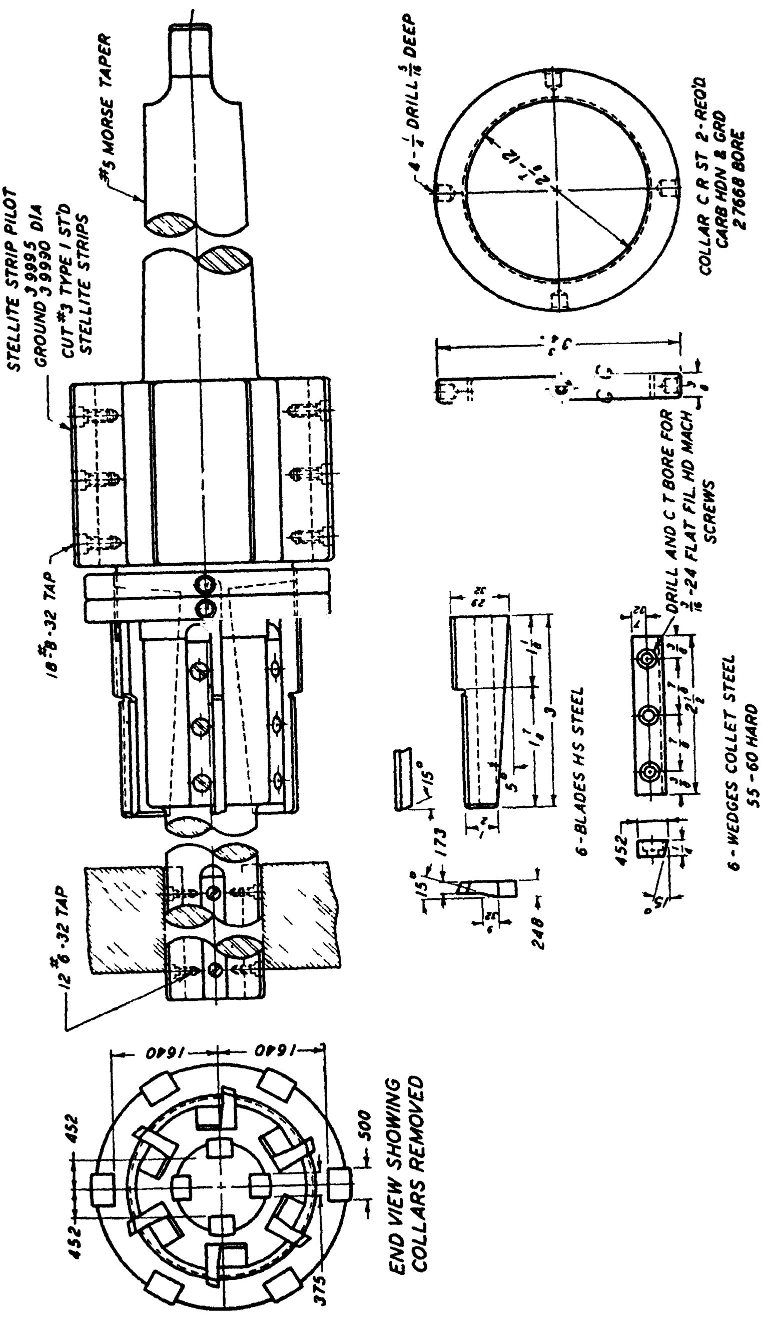


Fig 17B Details of Reamer Bar Shown in Fig 17A

multiple cutting heads are used simultaneously on a special double-end machine. The notched blade, as can be seen from the photograph, is formed by two separate blades performing the boring and counterboring operations, while the serrated blades, which start cutting after the boring blades, taper ream the hole. These serrated blades have alternately staggered nicks which break up the chip and make the tools cut easily. The facing operation for both ends of the coupling is done by the ring directly back of the cutter head. This has square tool bits mounted on each side so as to permit their adjustment for the required distance.

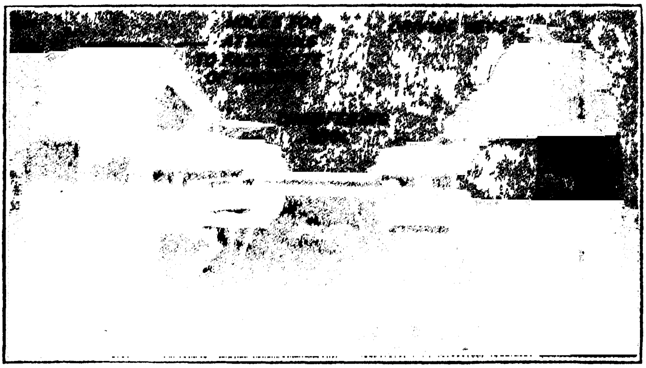


Fig. 18. Special Multiple Cutting Heads

You will note in this design that one of these multiple heads has a pilot bar that is located in the bore of the opposite multiple head. This maintains the proper alignment. Each one of these drill heads completes one end of a pipe coupling at one pass. Designing the tools so that these blades are readily removable for replacement considerably cuts down the ultimate cost of tools of this kind.

The initial cost of a tool designed in this manner is somewhat higher than that of a tool made from solid high-speed steel, but the solid tool would be more expensive in the end, because if any portion of a solid tool should break or become worn undersize, it would be necessary to scrap the entire tool. This would make the ultimate cost of a solid tool very high in comparison to that of one having an inserted blade.

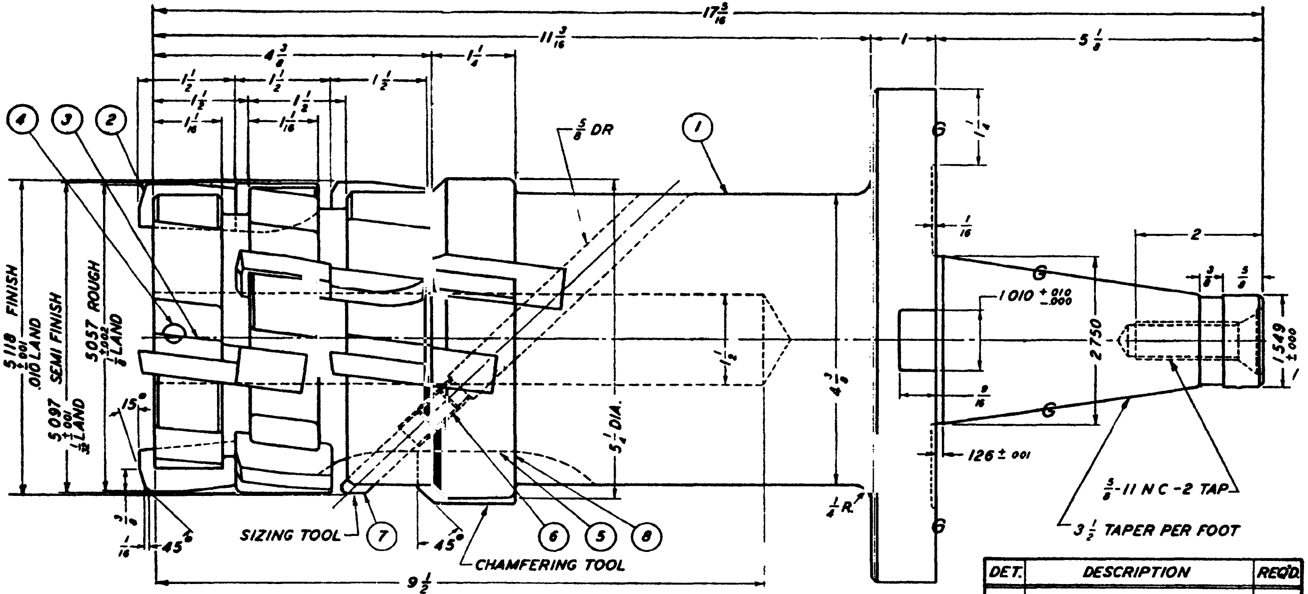
In designing tools for some of the multiple-spindle machines *it is often a requirement of production that the tools be designed* so that complete operations can be finished at one pass of the machine. For the transmission cover of a tractor where there are two or more holes that must be held to certain definite distances and to close limits of accuracy, tools are generally designed as shown in Figs. 19*A*, 19*B* and 19*C*. On the bar shown as Fig. 19*A* the inserted blades at the left rough finish, the next semifinish, the third finish the bore, all in one pass of the spindle head of the machine. These inserted blade tools are spaced so that one tool is entirely through the cut before the next tool begins to operate. In this way there is no possibility that one section of the cutting blades will interfere with the performance of the others. You will note in this design, in addition to the inserted blades, one single-point square tool bit, detail (7), that acts as a fly cutter or sizing blade. In this bar it will be noted that a chamfering operation is also performed by the addition of a blade set at the right point to perform the chamfering cut, which is made at a 45° angle.

The bar shown as Fig 19*C*, which is somewhat similar to the bar in Fig. 19*A*, performs three operations, a roughing, semifinishing, and a finishing operation. This bar also has a square tool bit that is used as a sizing tool. However, the chamfer is located in a different position on this bore and there is also a counterboring operation.

This design of bar is frequently used in automotive and tractor plants where it is necessary to secure quantity production and have accurately finished bores. Numerous combinations of this design can be employed to suit the needs of any particular job.

In the production of gate valves for high-pressure steam and hydraulic operations, etc., it is necessary to produce these valves in fairly large quantities. In addition, to withstand the pressure to which they are subjected, these valves must be machined very accurately. Therefore, the tools that are designed to perform these machining operations must be able to perform accurate work at fairly high rates of speed.

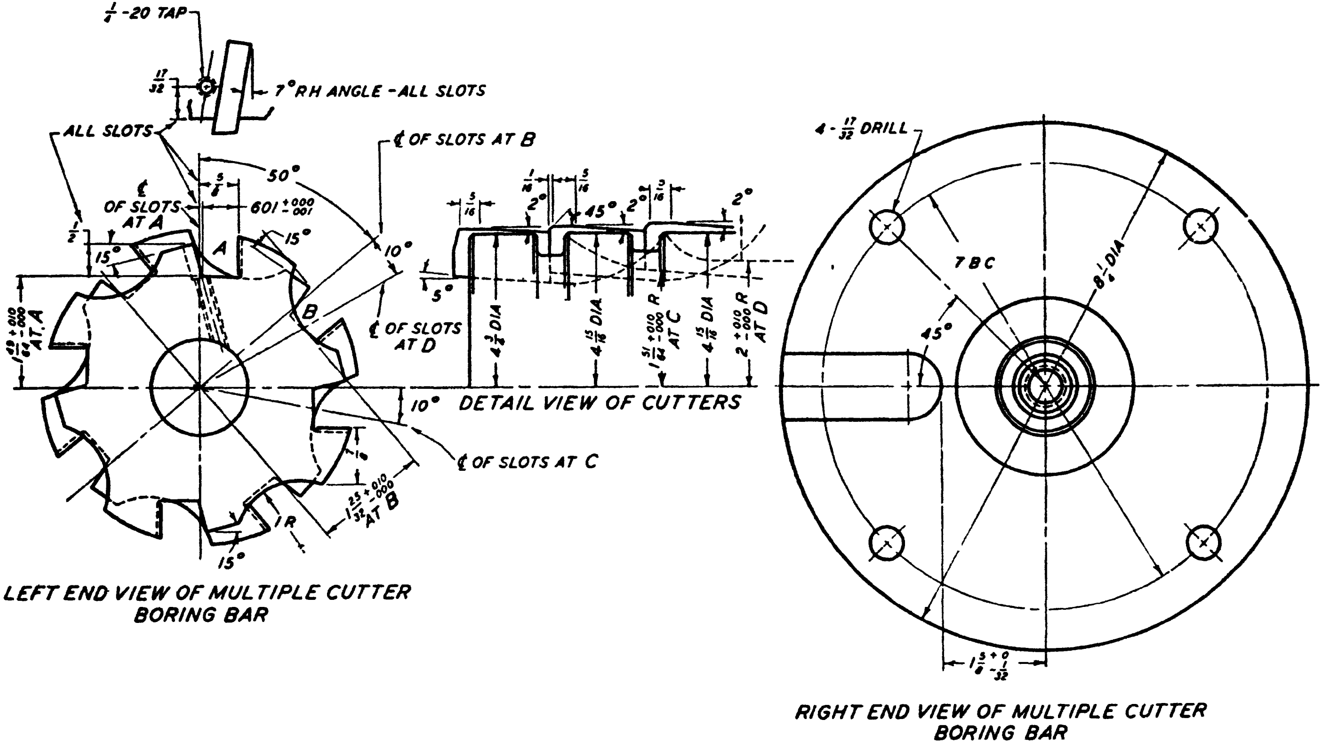
Cam-operated Combination Boring, Threading and Facing Bars. Fig. 20 illustrates a combination boring, threading, and inside facing operation. The first operation of this bar bores the diameter of a gate valve and, as the tool traverses through the cut, a lever on the



S A E. 3135 ST. HDN. AND GRD.
ROCK. 35 TO 37
STAMP TOOL No AND PART No

DET.	DESCRIPTION	REQ'D.
1	BODY	1
2	BLADE	12
3	WEDGE	12
4	SOCK HD. SCREW $\frac{1}{4}$ -20 x $\frac{5}{8}$	13
5	CHAMFERING BLADE	1
6	SOCK. SET SCREW $\frac{7}{16}$ -20 x $\frac{1}{2}$	2
7	TOOL BIT	1
8	WEDGE	1

Fig. 19A. Boring Bar Designed to Complete Several Operations at One Pass

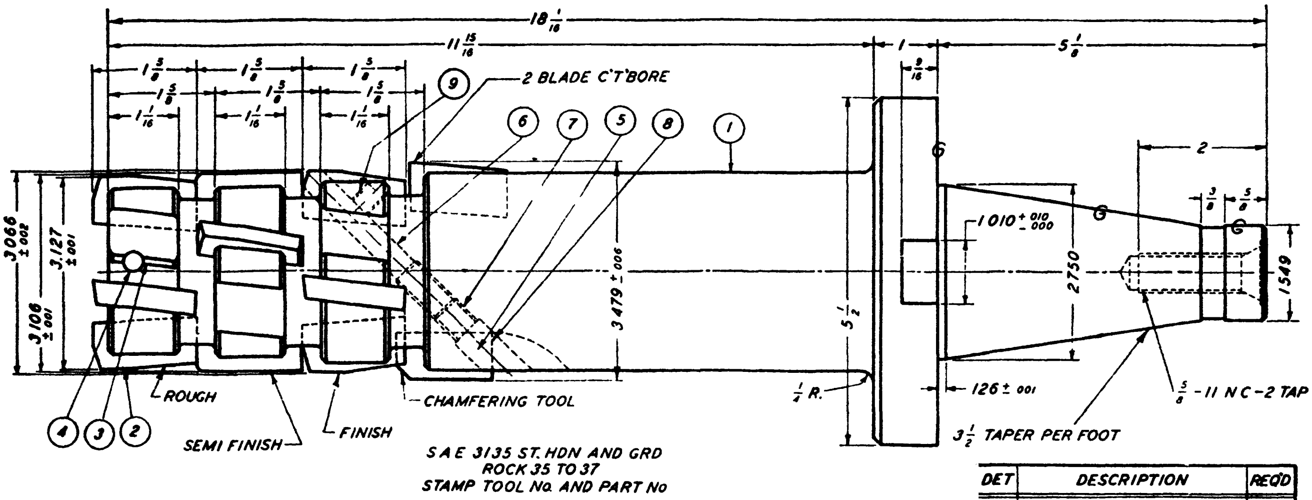


LEFT END VIEW OF MULTIPLE CUTTER BORING BAR

DETAIL VIEW OF CUTTERS

RIGHT END VIEW OF MULTIPLE CUTTER BORING BAR

Fig 19B. Details of Boring Bar Shown in Fig. 19A



DET	DESCRIPTION	REQ'D
1	BODY	1
2	BLADE	14
3	WEDGE	14
4	SOCK HD SCREW $\frac{1}{4}$-20 x $\frac{5}{8}$	15
5	CHAMFERING BLADE	1
6	TOOL BIT	1
7	SOCK SET SCREW $\frac{7}{16}$-20 x $\frac{1}{2}$	1
8	WEDGE	1
9	SOCK SET SCREW $\frac{3}{8}$-16 x $\frac{3}{8}$	1

Fig. 19C. Boring Bar which Performs Several Operations at One Pass

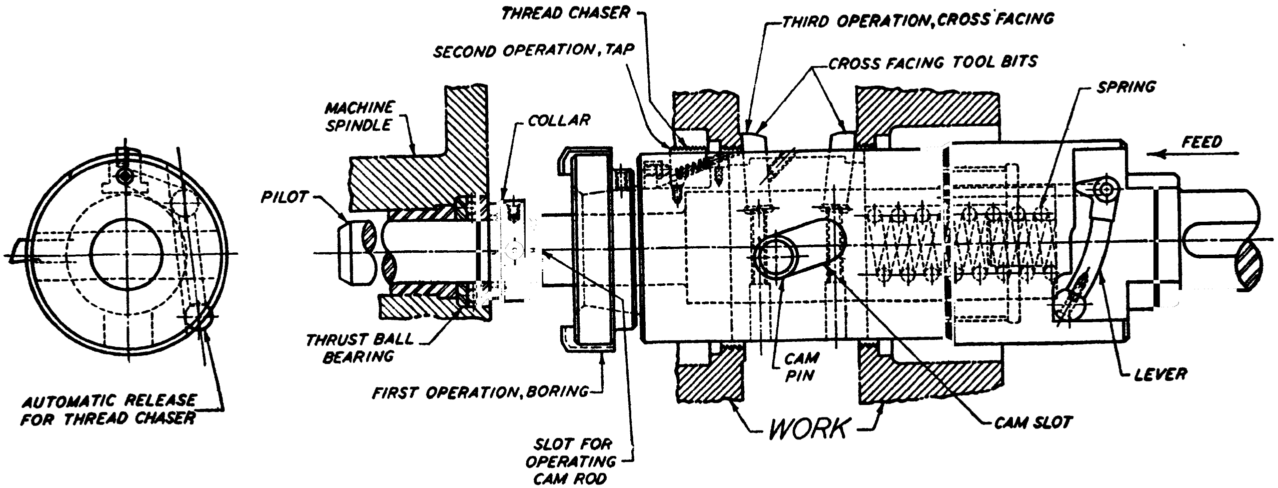


Fig. 20. Cam-Operated Combination Bar

shank portion of the bar operates the cam which controls the thread chasers. After these thread chasers perform the threading operation, the lever is released and they recede into the body portion of the bar. This completes the second operation; the third is as follows:

The pilot of the bar has a collar attached to it that is secured by means of screws. As the bar is fed through the work, this stop collar (which rotates with the bar) engages the thrust ball bearing stop, causing the cam pin to operate in the cam slot. This in turn actuates the 2 square tool bits which have been ground, then set, to the correct dimensions. These tool bits face the valve seat portion of the gate valve. The spring located in the rear portion of the bar causes the 2 square tool bits to recede, thereby allowing the cutting bar to be withdrawn from the work.

Bars of this design have numerous applications on high-production work; in some cases this design is the only type of tool that can be used to perform numerous operations on turret lathes, boring mills and other single-end or double-end special machines.

Tool Bits for Boring Bars. At the present time there is an almost infinite variety of tool steels that are available for tool bits. The designer must consider the various jobs individually. High-speed steel of a particular analysis might be satisfactory for one job and totally unsuited to another. The machine on which the boring bar is going to be used often determines the analysis of the high-speed steel tool bit that will be used in the bar. One error frequently made by tool designers in designing boring bars is that they do not provide a tool bit of sufficient size for the job. It is considered good practice to design the bar with a tool bit as large as possible, taking into consideration the diameter of the bar.

A boring bar with a 3″ diameter will not be weakened too much by putting in a 5/8″ square slot for the tool bit; moreover, the designer must keep in mind the fact that it is important to have a tool bit of sufficient size to radiate the heat generated by the tool bit in cutting the material on which the bar is to be used. Most designers make the mistake of having the tool bit entirely too small.

The use of Stellite as a tool-bit material for various grades of cast iron, brass, bronze, aluminum, etc., has proved very satisfactory on boring bars. However, the use of Stellite tool bits in boring bars must be given careful consideration, as this material will not stand the shocks (sometimes developed in boring) as well as high-speed steels. Where the tool bit does not have too much overhang (that is, where it does not extend too far out from the boring bar) Stellite will work satisfactorily on a great many boring jobs.

The design and shape of tool bits are determined by the job to be done. In many instances design and shape are developed in the plant by the cut-and-try method; for example, a tool is made to specifications as designed on the tool drawing, but after the boring bar with cutting tools in place is put into the shop it is found through some peculiar condition that it is necessary to change the shape of the cutting edges of the tool bit in the boring bar in order to obtain satisfactory results. Therefore, the tool designer's specifications for boring-bar tool bits are an approximation in a great many instances.

The use of tungsten carbide for tool bits for boring bars has had wide application during the last few years, and this material is somewhat in the same class with Stellite. The tool bits must be of sufficient size to stand the shock of the cut and to radiate the heat properly. No extensive overhang can be permitted with the use of tungsten carbide as tool bit material in boring bars, because the shocks of intermittent cuts that are sometimes encountered with the use of boring bars will cause tungsten carbide to chip off the tool shank. This will occur because it is really a tipping material; in other words, the tungsten carbide section is brazed to an alloy steel body. In the case of tool bits for boring bars it would be brazed on to a square section and then located in the boring bar the same as an ordinary high-speed steel tool bit.

Where proper rigidity and support can be given to tools tipped with tungsten carbide in boring bars they are ideal for a great many purposes, particularly on cast iron, brass, bronze, aluminum and other nonferrous metals, but consideration and good judgment must be exercised by the tool designer in specifying the use of these tipped boring tool bits.

The use of tungsten carbide tipped tool bits and boring bars on special double-end precision boring machines is constantly increasing due to the demands of the aircraft and automotive industries. Fig. 21 illustrates one of these special double-end boring machines for *roughing and finishing the boring of two aluminum aircraft pistons. The pistons are located in the fixture over a plug in the base of the* fixture. The pin holes are aligned with the spindles by cam-controlled fingers that are operated by a handle in front of the fixture. The pistons are clamped in the fixture by a hydraulic swivel clamp which descends on the top of them. The locating fingers are then moved out of the way. On one side of the machine are located the roughing boring bars; on the opposite side, the finishing bars. The roughing bars traverse through the work and then retract into the spindles. Then the finishing boring bars traverse through the work, finishing the pin bore of the pistons.

Formerly in machines of this type a diamond was mounted in the tool bit shank in the boring bar, but the cost of these tools was too great, although on aluminum pistons, for example, the commercial diamond would do a very satisfactory job. However, the use of tungsten carbide has largely eliminated the great initial cost of diamonds. Another difficulty in the use of diamond tool bits was the possibility of breakage which would sometimes occur despite all precautions. It will be noted in Fig. 21 that the design of the fixture is very simple and a cam clamping arrangement could be made if hydraulic operation were not practicable.

Another extensive use of tungsten carbide is also in the aircraft industry. Fig. 22 illustrates a double-end precision boring machine for machining both ends of a *master connecting rod* for aircraft engines, sometimes called an *articulating connecting rod.* In this machine, both ends of the connecting rod are machined simultaneously, which maintains perfect alignment of the bores as well as very accurate center distances. The large end of the rod is lined with babbitt and the small end has a bronze bushing. The machine is somewhat similar to that described in Fig. 21 except that the fixture is operated by hand instead of hydraulically. Tungsten carbide tool bits are used in both the roughing and finishing bars. To load this master connecting rod in the fixture, two pins are inserted in the articulating rod holes. These are a series of holes around the large end of the rod, as can be seen in the work at the base of the machine in Fig. 22. The lower pin is located in a **V**-block, then a flatted locating plug is inserted through the fixture in the small end of the master connecting rod. The hand knob at the top rear of the *fixture (see Fig 23) is tightened to clamp the large end of the rod* The hand knob shown on the front end of the fixture operates a spring jack that supports the small end of the rod Then the ratchet hand knob shown on the top front of the fixture is tightened to hold the small end of the rod in proper position The flatted locating plug is then removed from the small end of the master rod. The machine roughs and finishes the bores to the correct size This fixture is comparatively simple and the design can be employed on many other similar types of jobs

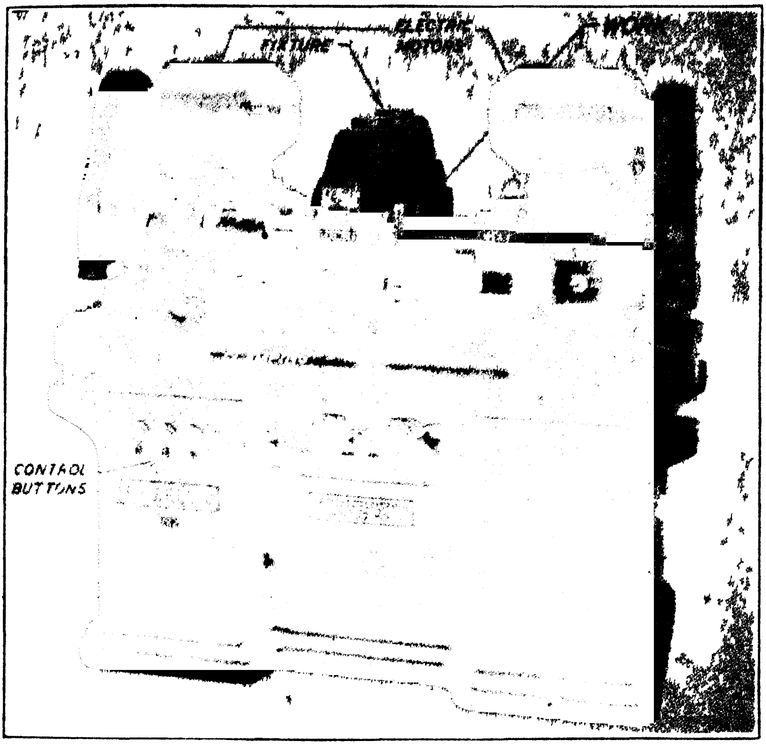


Fig 21 Special Double End Precision Boring Machine for Roughing and Finishing Aluminum Aircraft Engine Pistons

Courtesy of Ex-cell o Aircraft and Tool Corporation Detroit Michigan

Fig 23 shows a closeup view of the spindles and fixture that were described in connection with Fig 22. It will be observed that the rod is in a position to be unloaded from the fixture. It will also be noted from the design of the bars that they are made as short as possible to overcome any springing away from the work.

Rigidity is very important in bars designed for jobs of this type, because in some cases it is impossible to use a guide bushing for machining parts such as the inner bearing cage shown in Fig. 24.

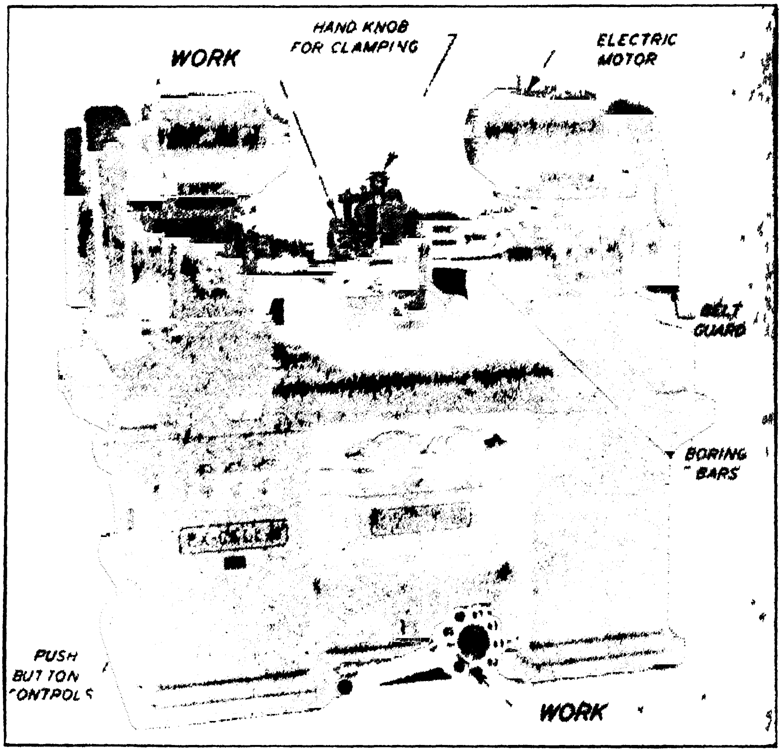


Fig 22 Double-End Precision Boring Machine for Rough and Finish Boring Both Ends of Connecting-Rods Used in Air-Cooled Aircraft Engines
Courtesy of Ex-cell-o Aircraft and Tool Corporation, Detroit, Michigan

It will be noted from the dimensions on this drawing that the diameter of the bore (3.9364″ to 3.9374″) is very close, as there is only .001″ tolerance. This is necessary because an antifriction bearing must be inserted in this part. Therefore, to bore this hole to the specified limits requires a precision boring machine such as has been described. In this instance a single-spindle machine would serve unless the production requirements were large, in which case a four-spindle machine such as previously described could be used and a fixture designed to accommodate four pieces at one time.

Fig. 25 shows the design of an adapter for a precision boring machine and the boring bar. This fixture consists of a face plate that is carburized, hardened, and ground to a close dimension to fit the machine spindle. The piece part, Fig. 24, is mounted in the central section of this adapter plate and clamped by means of two clamps shown located on the vertical center line 180° apart. This fixture necessarily must be very accurate in order to locate the work on the outside diameter, and is held to a +.0005 limit. The tool bits used for machining this part are tipped with tungsten carbide. One tool bores the diameter shown as 3.9364 to 3.9374, and the other faces the bottom to .956″ to .958″ dimension. The setup shown by Fig 25 is commonly used and is one of the fastest and best ways to produce parts similar to those shown in Fig 24, because once the bar and adapter are located on the machine in the proper position it does not require much skill or effort on the part of the operator to produce parts in quantity to very close accuracy.

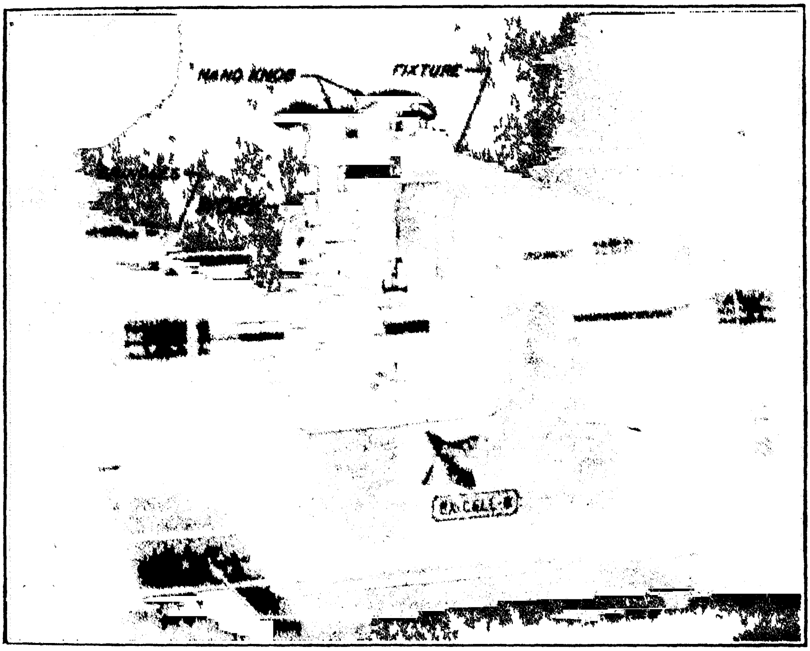


Fig 23. Closeup View of the Spindles and Fixture for the Machine Shown in Fig 22
Courtesy of Ex-cell-o Aircraft and Tool Corporation, Detroit, Michigan

Multiflute Drills. In order to determine the design and type of cutting tools to be used for a given job, it is necessary that the tool designer know the type of machine that is available and the number of pieces required. If the job is a simple one, such as can be done in the average drill press or turret lathe, and if the material is a steel forging and the operation required is drilling a two-stepped hole, he will design a tool similar to that shown in Fig. 26. This tool is commonly termed a *sub-land* or *multiflute* drill, so named because the flutes for the two diameters are separate and distinct. A tool of this design is capable of drilling a hole in solid metal and has the added advantage that two machining operations are performed at the same time. This design of drill is frequently

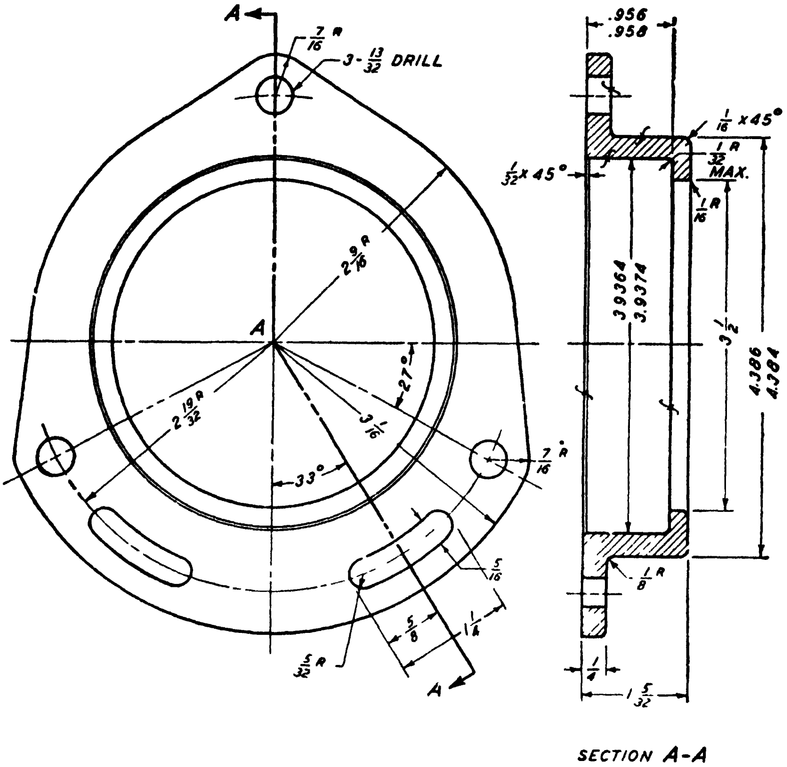


Fig. 24. Cast-Iron Inner Bearing Cage

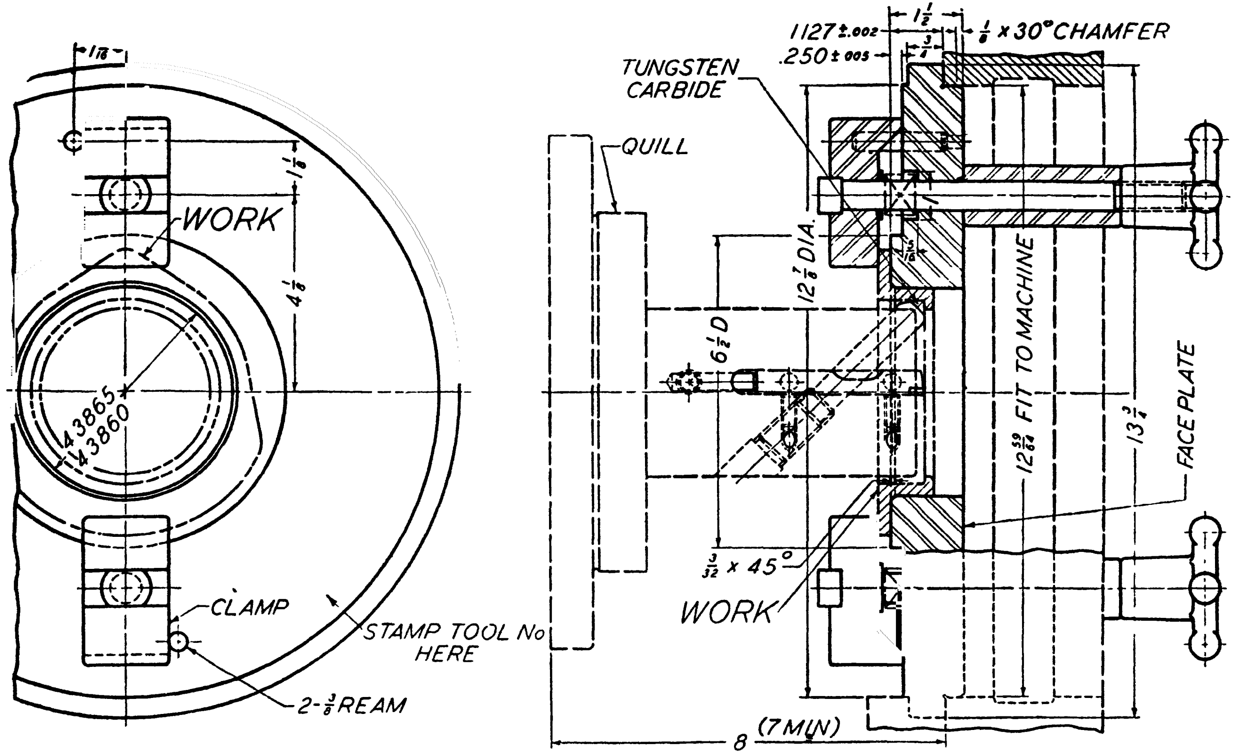
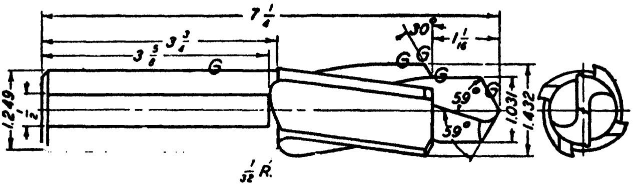


Fig. 25. Adapter for a Precision Boring Machine and the Boring Bar

used, particularly on large production where it is desirable to cut costs to a minimum.

This same principle of design can be incorporated in a tool that will machine three or more diameters, as shown by Fig. 27. The drill section opens up the hole in the solid metal, the next tool comes into position and counterbores, and the last section of the tool performs a facing operation. When designing tools of this kind it is sometimes necessary to work from a previously machined hole and then open up two or more diameters to the required dimensions. A tool designed as shown in Fig. 28 is then used.



H.S.S. HDN. AND GRD.

Fig. 26. Sub-Land or Multiflute Drill

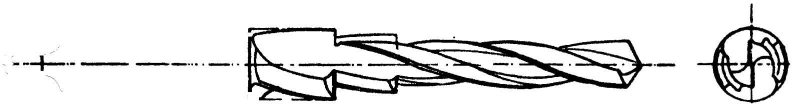


Fig. 27. Drill to Machine Three Diameters

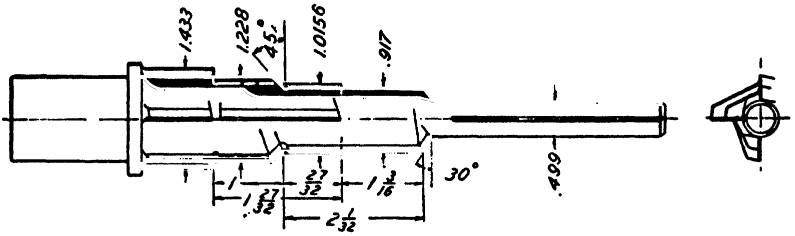
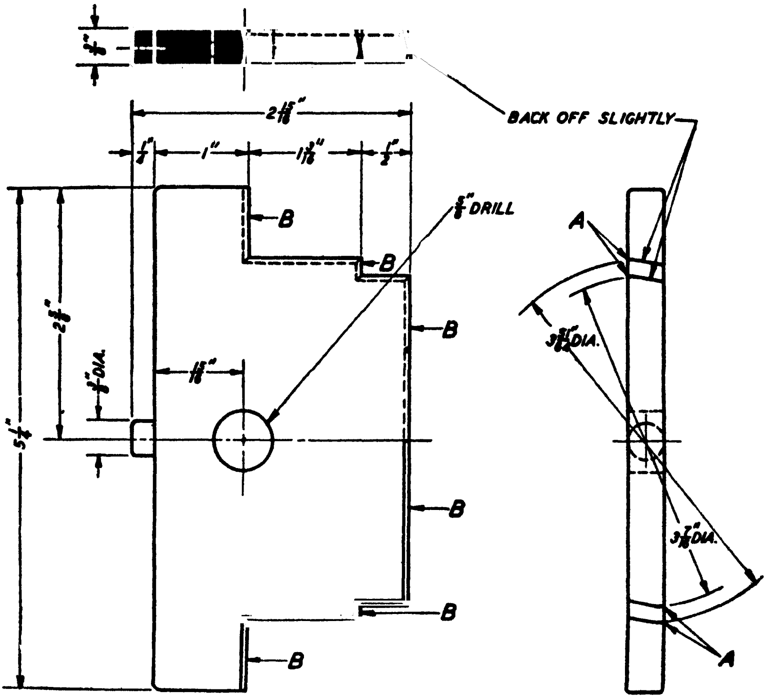


Fig. 28. Drill to Work from a Previously Machined Hole

On low-production jobs where tooling expense must be kept to a minimum and where the part is designed to be made of cast iron, the operation on the part may call for opening up this cored hole to provide a bore, counterbore, and facing operation. To do this, a tool such as that shown in Fig. 29 is used. This tool is de-

signed to be made of a piece of flat high-speed steel and is to be used in a holder, usually in a turret lathe. The ⅝" drill hole shown in the design is for clamping the cutter in position in the holder. There are any number of combinations of flat high-speed tools of



COUNTERBORING & FACING TOOL
HIGH SPEED STEEL 1 REQ.
HARDEN & GRIND

Fig. 29. Combination Tool for Facing and Counterboring a Bronze Casting in a Turret Lathe

this type which can be designed to suit the needs of various jobs. A tool of this design can be produced at small cost and, while it does not cut as fast or last as long as a multiflute tool, it will perform satisfactory work under the usual shop conditions.

Fig. 30 illustrates a multiflute tool for producing various diameters. Tools of this design, however, must be used after roughing operations have been performed on the part, or in a previously machined part. Note that each flute is individual and the tool may be ground on these various diameters without interfering with other parts of the tool. In other words, it is possible to maintain definite dimensions on the various steps of the bore.

Various combinations of these tools can be designed. Fig. 31 illustrates a special combination tool that is piloted in a fixture to operate in a cored hole in a casting. This tool core drills, reams, counterbores, and faces a portion of a pump casting. The design of this tool is such that each portion of these cutting sections is removable and can be replaced in the event it becomes worn undersize or broken. This design is capable of almost unlimited adaptations to suit the jobs in question.

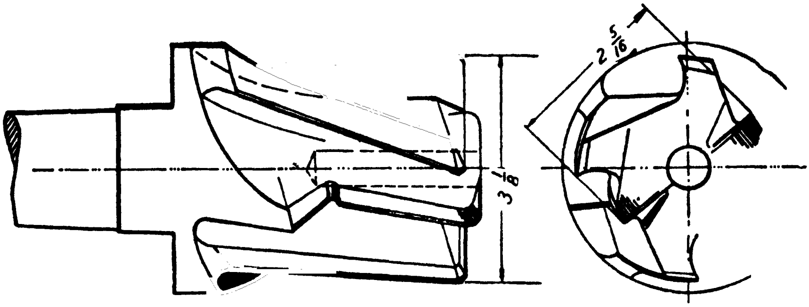


Fig. 30. Tool for Producing Several Diameters

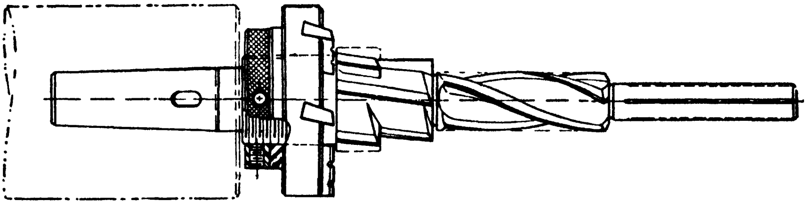


Fig. 31. Special Combination Tool Piloted to Operate in a Cored Hole

Fig. 32 illustrates a combination of multiflute tool, inserted blades, and a combination hollow milling, facing and chamfering tool. This tool illustrates the combinations of design that can be employed to perform certain required machining operations. A 2-flute drill is used to open up the hole to the required diameter, then this special combination tool is employed to perform all subsequent operations at one time. A tool of this design insures absolute concentricity of these various diameters.

Special Cutting Tools. Standard cutting tools such as drills, reamers, taps, dies, and milling cutters can be obtained in most cases from manufacturers' stocks, but there are numerous instances in the metalworking plants where it is necessary for the tool designing department to produce certain special cutting tools; therefore it is well for the tool designer to have some knowledge of these types of tools. Oftentimes the standard tools can be readily adapted by means of slight changes that can be made in the plant tool room, either by grinding or by other machining operations. Taper reamers are usually designed especially for the use of individual plants.

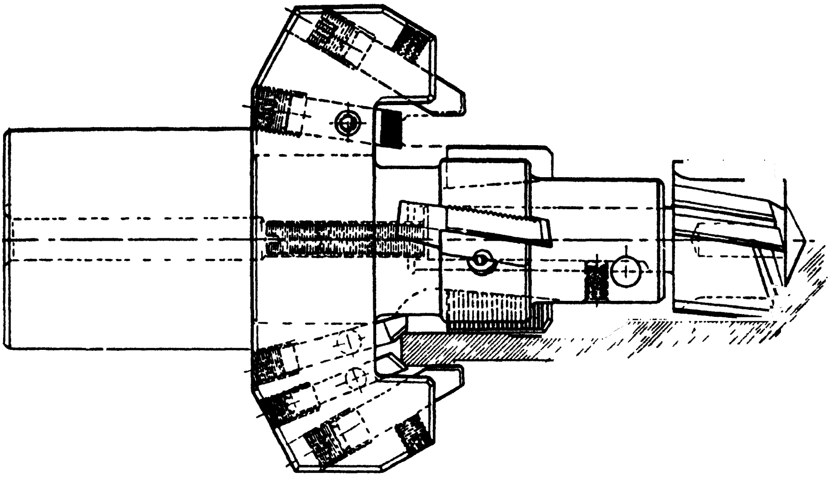


Fig 32 Combination Multiflute Tool

Fig. 33 illustrates a design of roughing and finishing taper reamers. (*A*) illustrates the design of a roughing reamer; the flutes are straight and have a slight taper to the small end of the reamer. Nicks on the flutes are staggered to break up the chip and prevent the reamer from binding in the work. This is always considered good practice as it permits the reamer to cut more freely. The finishing reamer (*B*) is made with helical flutes. This design permits the reamer to produce a very good finish in the work. In designing finishing reamers the land or cutting edge should be very narrow, not over .004″ or .005″. In some plants it is considered

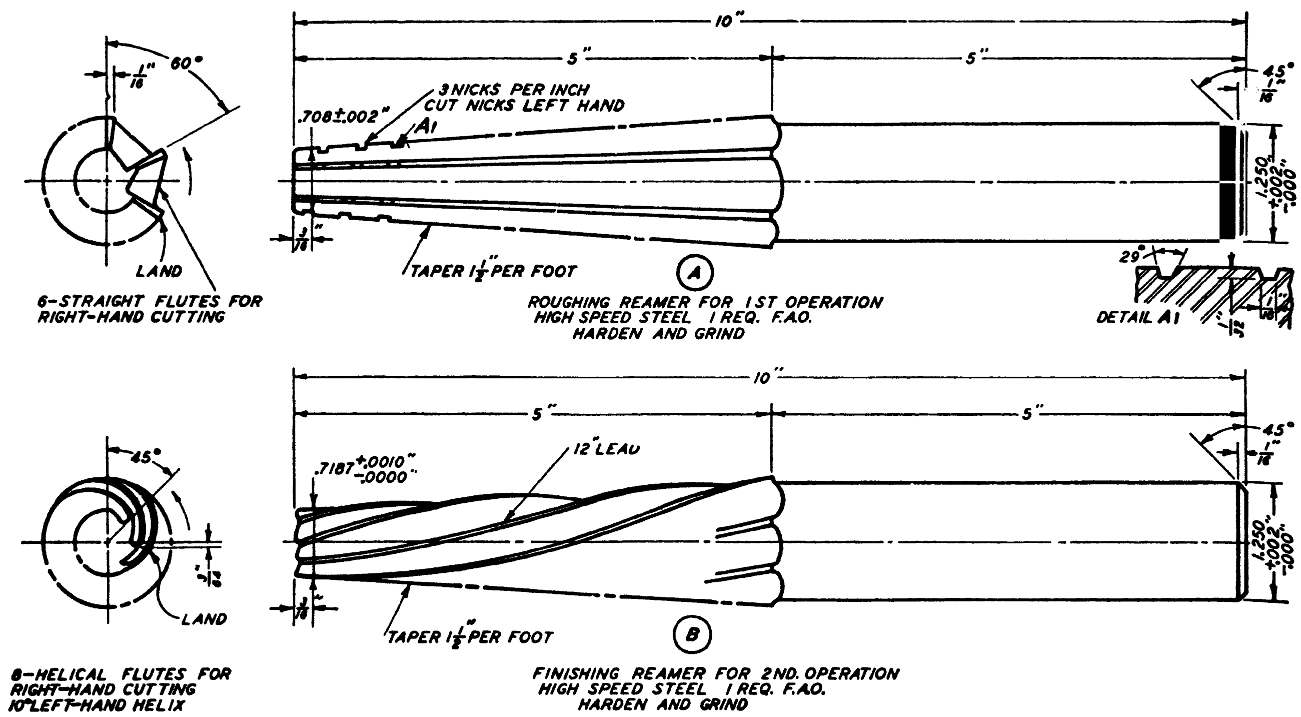


Fig. 33. (*A*) Roughing Reamer, for First Operation; (*B*) Finishing Reamer, for Second Operation

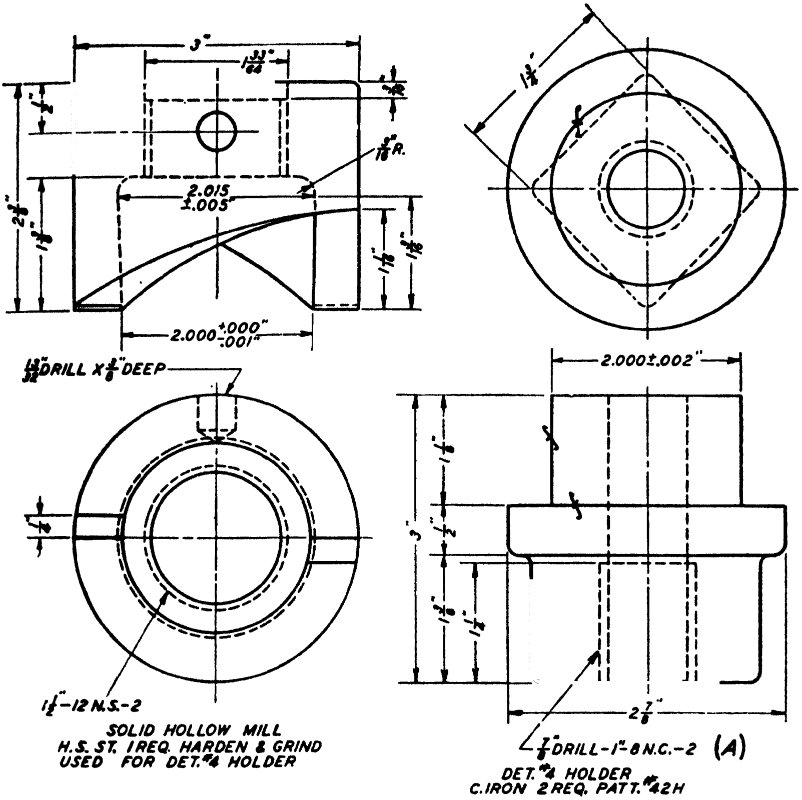


Fig. 34. Hollow Mill for Machining a Cast-Iron Holder (*A*)

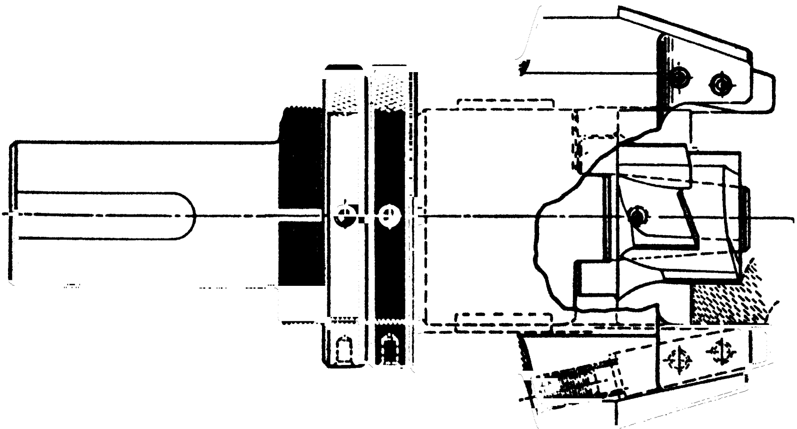
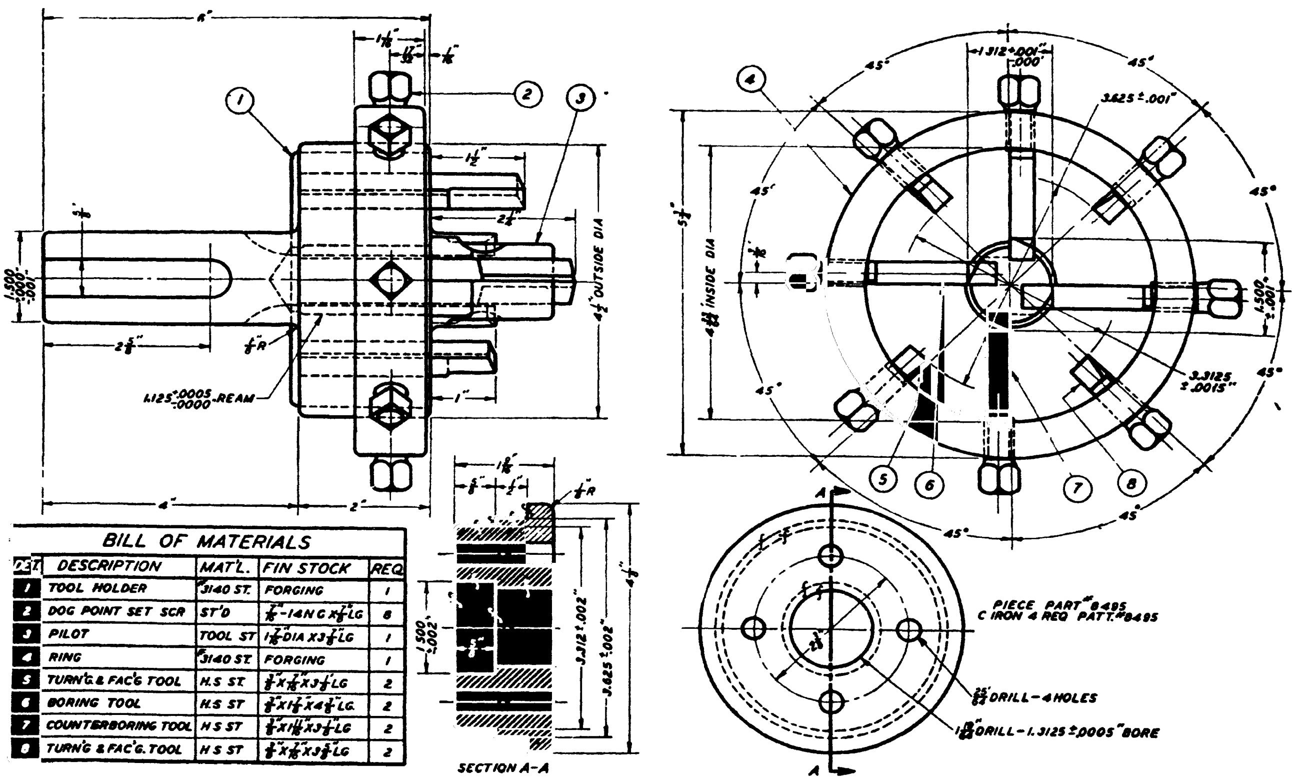


Fig. 35. Combination Hollow Mill, Boring, and Counterboring Job



BILL OF MATERIALS

DET.	DESCRIPTION	MAT'L.	FIN STOCK	REQ
1	TOOL HOLDER	#3140 ST.	FORGING	1
2	DOG POINT SET SCR	ST'D	7/16"-14NC X 7/8" LG	8
3	PILOT	TOOL ST	1 7/16" DIA X 3 7/8" LG	1
4	RING	#3140 ST.	FORGING	1
5	TURN'G & FAC'G TOOL	H.S ST.	3/8" X 7/16" X 3 1/8" LG	2
6	BORING TOOL	H.S ST	3/8" X 1 1/8" X 4 7/8" LG.	2
7	COUNTERBORING TOOL	H S ST	3/8" X 1 11/16" X 3 1/8" LG	2
8	TURN'G & FAC'G. TOOL	H S ST	3/8" X 7/16" X 3 5/8" LG	2

FIG. 36A. Multiple Tool for Boring, Counterboring and Turning Piece Part No. 8495

good design not to have any land on the finishing reamer blades, because such blades produce better results on some types of work.

Hollow mills are available commercially in both the solid and adjustable types. On some classes of work the demands of the job

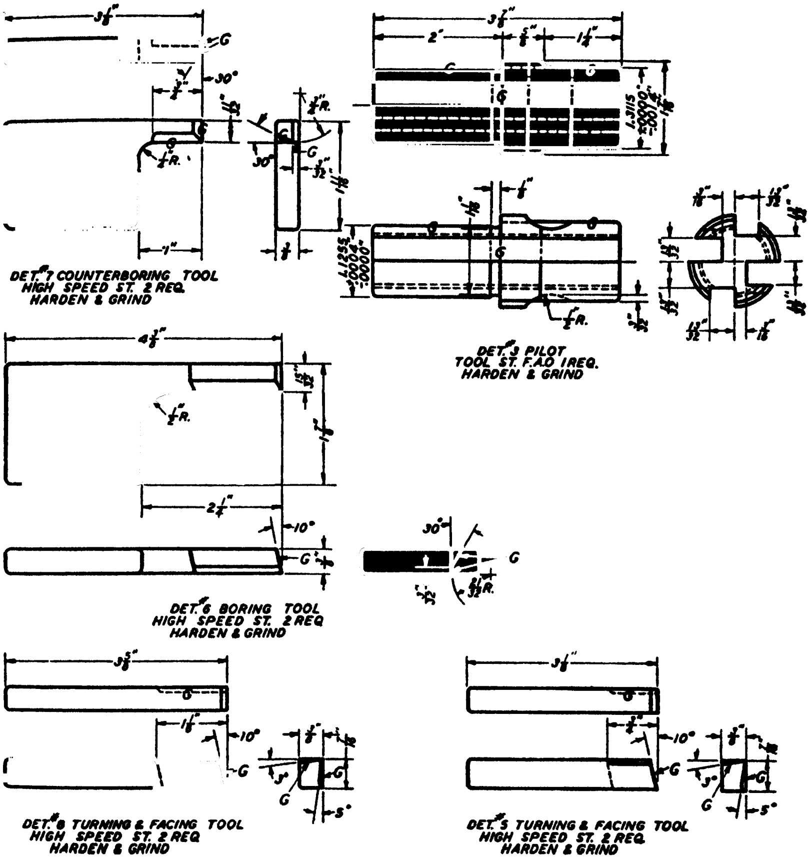


Fig. 36B. Counterboring, Boring, and Turning Tool Details

make it necessary to design a hollow mill in the plant. Fig. 34 illustrates a hollow mill for machining a cast-iron holder. This is a 2-flute hollow mill to be made from high-speed steel. Usually solid hollow mills are made much smaller in diameter than the one illustrated. Combinations of these can be designed so as to produce steps of various diameters on the part, or in some instances they can be used in conjunction with other tools. Fig. 35 illustrates a combina-

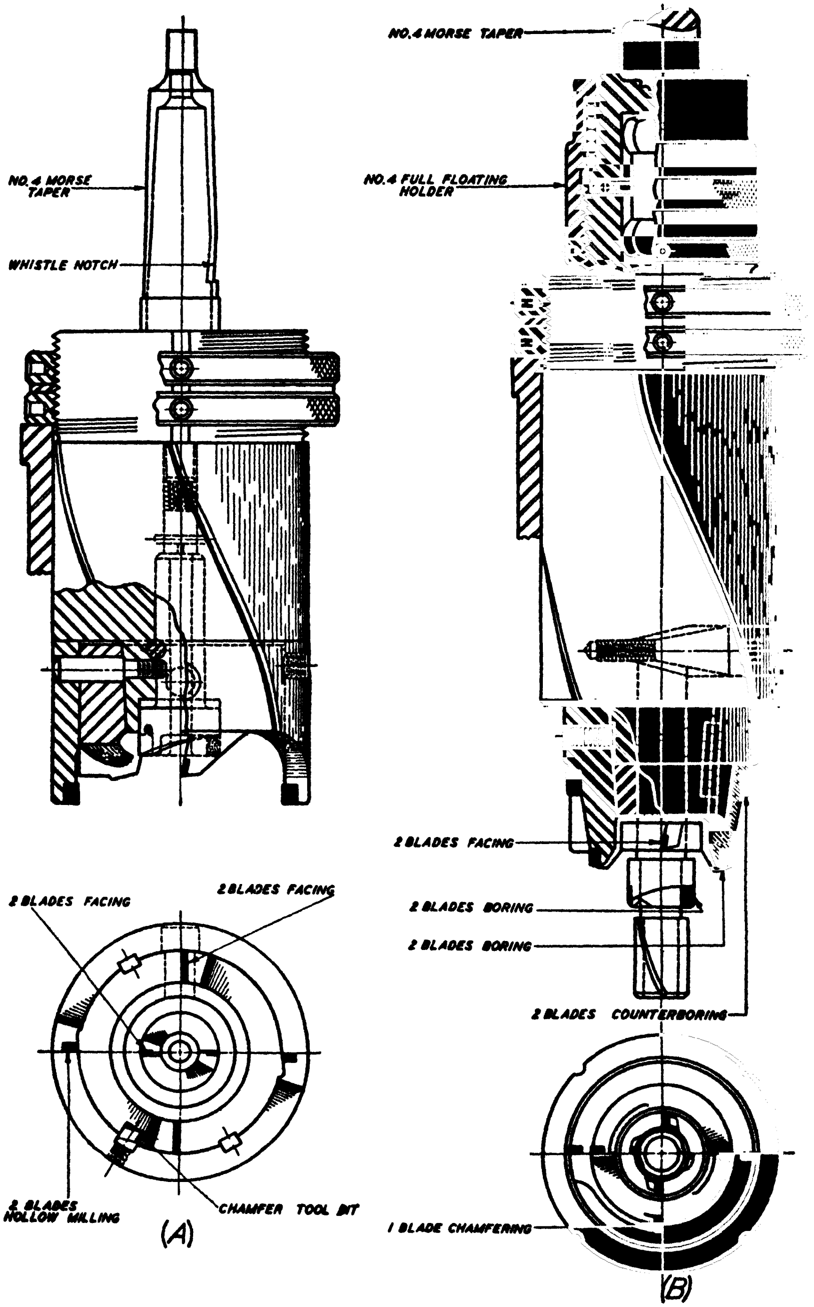


Fig. 37. (*A*) Special Tool for Facing, Hollow Milling, and Chamfering Piece Part No. 15775 (High-Production Tool); (*B*) Special Tool for Facing, Boring, Counterboring, and Chamfering Piece Part No. 15775 (High-Production Tool)

tion. hollow mill, boring, and counterboring job. This design is used extensively in the automotive and tractor industries. The only objection to this type of tool is that it is necessary to take the complete tool out of the machine for regrinding of the hollow mill section when it becomes dull. The central section, which is of solid high-speed steel, is quickly interchangeable.

Combination tools of high-speed steel which have square tool bits and flat cutting blades are illustrated by Figs. 36A and 36B.

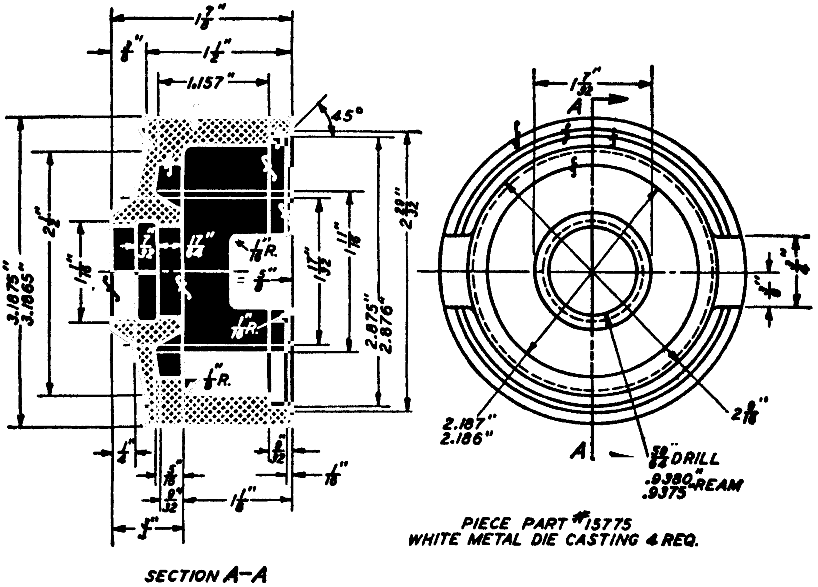


Fig. 38. Production Drawing of a Die Casting

They are extensively used in plants machining brass or bronze, although tools of the same design can be used on steel or cast iron. It will be noted that this tool machines the internal dimensions, performing a boring and counterboring operation, as well as turning three distinct steps on the outside diameter of the work. The cost of making these tools is quite low in comparison to other types of tools that could be employed, but the expense of regrinding and of setting up to secure the correct dimensions is a disadvantage. However, this tool is ideal for performing the various operations on certain classes of work.

On jobs where there are a number of sections to be machined and where it is necessary to finish both the inside and outside diameters, special combinations of tools are employed as illustrated by Fig. 37 and 38. The work, Fig. 38, is a die casting. This material, which is an aluminum alloy, is ideal for the use of tungsten carbide; therefore the tools, Fig. 37, have been designed to use this material for the cutting sections. (*A*) of Fig. 37 illustrates a combination boring, facing, and hollow milling tool, while (*B*) illustrates the design of a tool for finishing the internal diameters of the part shown in Fig. 38. This tool has been designed so as to permit the various dimensions shown on the work piece to be held to definite dimensions, for it is possible to grind these tools so that they will be concentric with each other and so that the steps will be to the dimensions required. Unlimited combinations of this design can be developed by the tool designer when confronted with jobs of this type.

QUIZ QUESTIONS

1. What are some of the factors that must receive careful consideration before cutting tools can be designed?

2. Why is it good practice to consult the foreman of the production department before specifying materials for cutting tools?

3. Why is a thorough knowledge of available standard tools valuable to the tool designer?

4. Why are broaching operations constantly increasing in the machine manufacturing industry?

5. What determines the pitch of the broach teeth in the design of keyway broaches?

6. What operation in a number of jobs in the automotive industry is external broaching replacing?

7. What are some of the important points that must be recognized in the design and construction of a boring bar?

8. What are the general classifications of material for boring bars?

9. What type of shank is most commonly used for boring bars?

10. Before beginning the design of a boring bar, what factors must the tool designer consider?

11. When a boring bar contains various tools covering different operations, what important design practice must be followed in the arrangement of the tools to produce the greatest accuracy?

12. In the design of reamers used in connection with a reaming bar, how many cutting edges or flutes should be included?

13. In the boring bar shown in Fig. 19A, how many cuts are taken in one pass of the spindle head of the machine?

14. In designing boring bars with tool bits, what common error is made by tool designers with regard to the size of the tool bit?

15. What tool-bit material is commonly used in machining cast iron, brass, bronze, and aluminum?

16. In what industries are the tungsten carbide tipped tool bits and boring bars being used in increasing number?

17. What are some of the difficulties encountered in the use of diamond tool bits mounted in boring bars?

TOOLING FOR PRODUCTION

AUTOMATIC SCREW MACHINES

The principles of automatic screw machines (Fig. 1) are quite simple and are as follows: the material to be machined is usually in the form of bar stock, which can be round, square, hexagon or some other shape. This bar stock is held tightly in the spindle of the automatic screw machine by means of a spring collet and is rotated by two pulleys on the spindle which is driven by a belt from the countershaft or motor. The pulleys run free, and either one or the other is engaged to drive the spindle by means of a friction clutch that is inserted between pulleys. This gives a spindle drive that allows the speed or direction of rotation to be changed or reversed. The cutting operations are performed on the bar stock by means of cutting tools that are held in the turret and on the cross slides. The wide variety of work that can be produced by automatic screw machines is limited only by the tools that can be designed and made for these various jobs.

The turret of an automatic screw machine has six ports or tool posts and is automatically indexed to bring each tool in the proper position. The cross slides are two independent slides at right angles to the spindle of the automatic screw machine. Both the turret and the cross slides are moved to and from the work by means of special cams that are designed to give the proper feed to each tool. In other words, these cams actuate the tools in and out over the bar stock to perform the necessary machining operations for the piece to be produced. The bar of stock is automatically fed forward to the new cutting position after each piece has been completed. The pulley on the driving shaft at the rear of the machine is driven at a constant rate of speed regardless of the spindle speed. By means of clutches mounted on this shaft, it controls the operation of all idle movements of the machine, such as indexing the turret, feeding the stock, and reversing the spindle. This shaft also drives the turret and the cross-slide camshafts through a series of change gears. On the cross-slide camshaft there are mounted three trip-dogs which carry operating levers that control the operation of clutches on the driving shafts. These trip dogs are adjustable and can be set to trip the clutches at the desired time.

Fig. 1 illustrates an automatic screw machine designed to produce small work. The principles of all these machines are practically the same, and the tools that are designed for use with them are almost identical except for size. These automatic screw machines are particularly adapted to the use of a wide variety of special tools and attachments for performing difficult machining operations. The kind of work that can be handled is almost unlimited. These tools must be specially designed for the peculiar requirements of jobs.

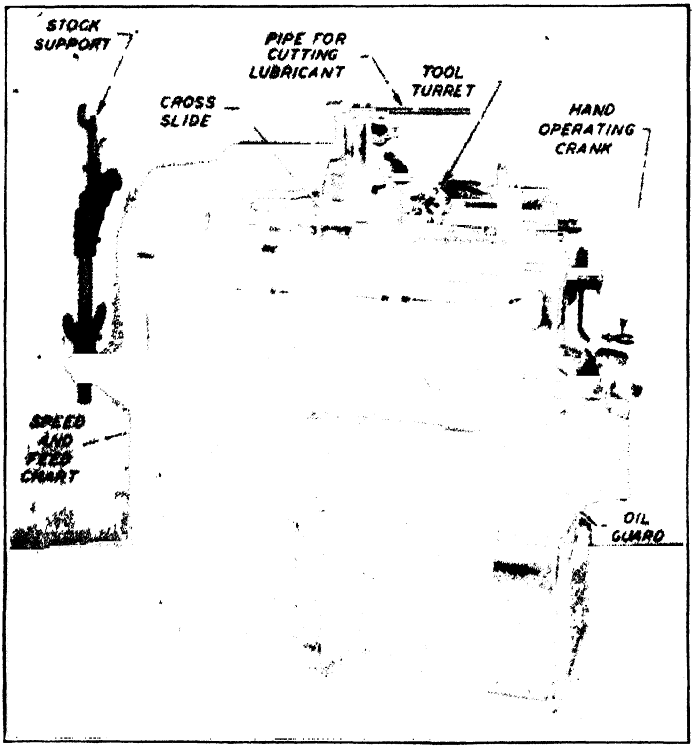


Fig 1 Automatic Screw Machine
Courtesy of Brown & Sharpe Mfg. Co, Providence, R I

Circular Forming Tools. One type of cutting tool most frequently used in conjunction with automatic screw machines is the circular form cutter, Fig. 2. These circular forming tools are usually made of high-speed steel and, as can be seen from the illustration, they are designed so that in one cut they will machine the contour.

In designing circular forming tools it is necessary for the designer to know the type of machine they are to be used on, so that he can incorporate in his drawing the correct outside diameter, the proper width, and the particular size of hole in the center of the circular forming tool. This center hole is used to attach it to the circular forming tool holder that is mounted on the cross slide of an automatic screw machine. These tools are turned up in a lathe to the required outline and dimensions, and are hardened and then ground to the finished size; then a section is cut away to provide the proper cutting face.

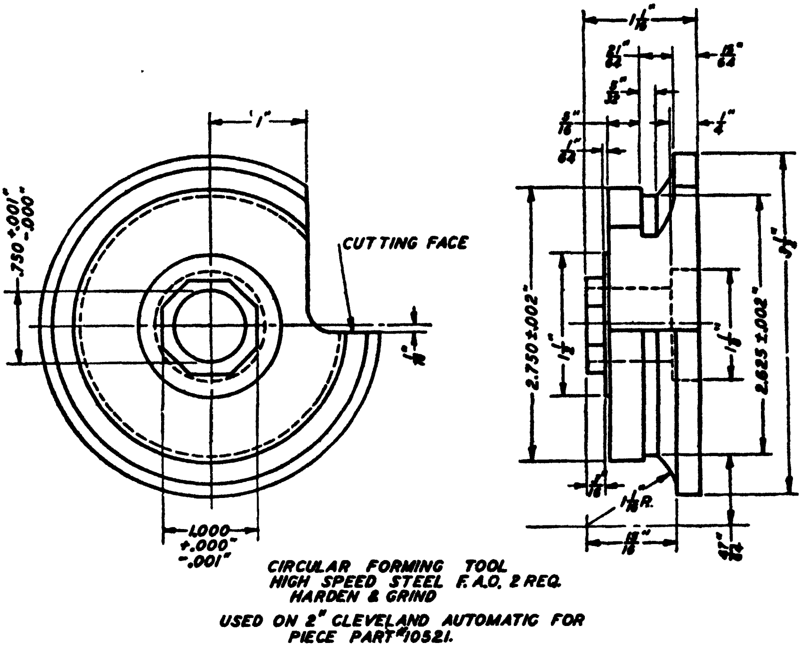


Fig. 2. Circular Forming Tool for Turning, Facing, and Forming in an Automatic Screw Machine (High-Production Tool)

The outstanding advantage of circular forming tools is that they do not change their shape and it is necessary to grind only the top of the cutting face; the contour of course remains the same. As this section is ground away, the circular forming tool is reset in the tool holder so as to bring the cutting face on the center line of the work.

Standard Tools for Automatic Screw Machines. The automatic screw machine is capable of producing work with a very high degree of accuracy, with a fine finish, and at a very rapid rate; this of course is true only if the designer selects the right type of tools for the job. He should keep in mind, however, that the simpler the design of the tool, the less the possibility of difficulties. It is essential that the tool designer who must design tools for these machines know something of the standard tools which are available. In some instances these standard tools can readily be converted into use for special jobs by slight alterations or changes in the setting of the tool bits or blades; therefore a description of these standard tools is essential.

Fig. 3 illustrates a group of standard tools for automatic screw machines. In specifying standard tools, care should be taken to see that the right size is designated and that the correct type is used. The external turning tools, balance turning tools, plain hollow mills, adjustable hollow mills, box tools, swing tools, and knee tools are all used in the turret. The centering and facing tools, pointing tools and pointing tool holders with circular tools are for operations on the end of the work. The internal cutting tools, drills, counterbores, and reamers are held in drill holders or floating holder and recessing tools. These are similar to tools used on various other types of machines and therefore no general description of uses will be given.

The threading tools, such as taps, are held in tap holders; dies are held in die holders; chasers are mounted in self-opening die holders; and thread rolls are held in cross-slide holders or in knurling swing tools. Knurling tools and top and side knurl holders are used on cross slides. The adjustable knurl holders and knurling tools are used in the turret. Forming and cutting-off tools, circular forming tools, and circular cutoff tools are used in the regular cross-slide tool post and in an adjustable tool post. Square tools and thin straight blade cutting-off tools are all used in the cross slide. The angular cutting-off tools, support and auxiliary tools, back rest for turret, back rest for swing tools, back rest for chucks, fixed and adjustable guides for operating swing tools, and spindle brake are all used in the turret.

The following suggestions to the tool designer will be of help in selecting the correct design and type of tools for the automatic screw machine. The balance turning tool is the best all-round tool for straight rough turning. Plain hollow mills and adjustable hollow

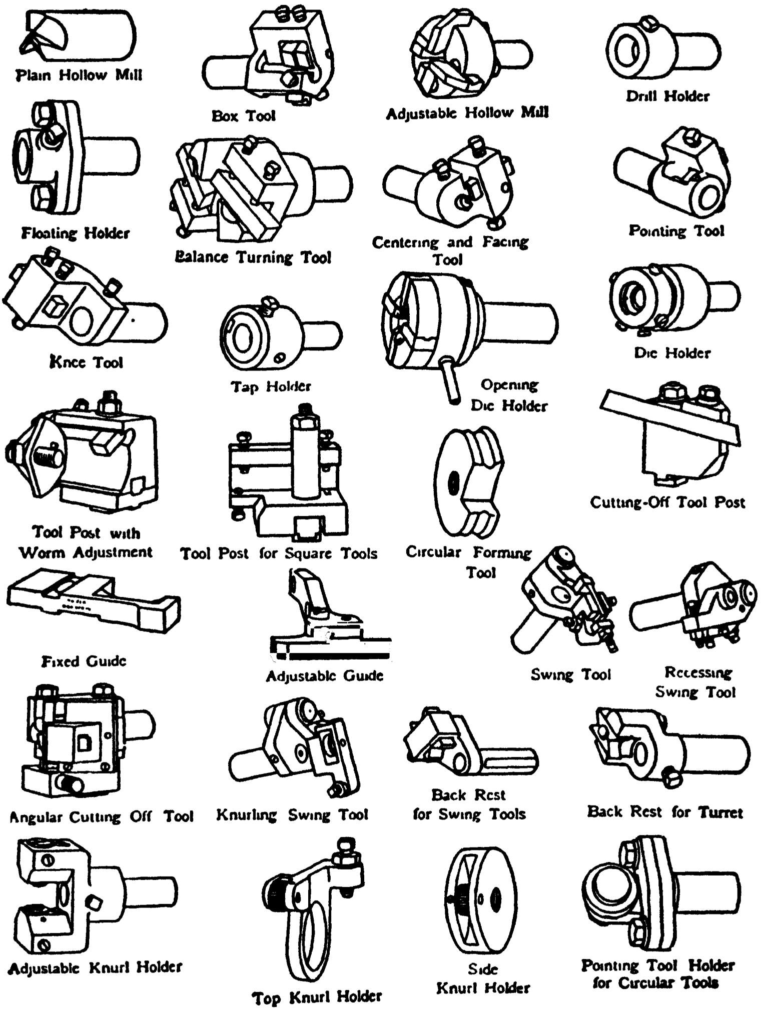


Fig. 3. Group of Standard Tools for Automatic Screw Machines
Courtesy of Brown & Sharpe Mfg. Co., Providence, R.I.

mills can also be used for jobs of this kind. For straight finish operations, turning box tools are preferable. The knee tool is designed for turning scale on black bar stock; that is, stock that is termed hot-rolled and does not have the finish that is usually found in screw machine bar stock. On straight turning where the piece is long and very slender, a pointing tool of the box type is considered better than any other tool because the stock is held in the bushing ahead of the blade that machines, and this tends to hold the work steady.

For all taper turning, the swing tool is the most generally used tool. This type of tool can also be applied on some types of form turning where the curve is long or very shallow and continuous. Swing tools are sometimes used in place of circular forming tools. The circular forming tools on the cross slide are generally used for all form turning and for straight turning behind shoulders. This of course is where the length of cut is not too large in proportion to the diameter of the work.

For centering work in a screw machine, a center drill is mounted in a floating holder; this permits ready alignment. To round off, chamfer, or point the end of the work (where it is stiff enough so it will not spring in the operation) a pointing tool holder with a circular tool can be used, due to the fact that this design of tool permits it to be used indefinitely, as it is similar to a circular forming tool and can be ground without changing its form. Drills, reamers, and counterbores should always be mounted in screw machines with a floating tool holder so that they may easily be adjusted to center with the work.

Fig. 4 illustrates various types and forms of circular forming and cutting-off tools. Looking at *A*, it will be seen that on this particular part both cross-slide tools do the forming, and the piece is fed out before the cutting-off operation takes place. This idea can be used where there is a shoulder where the portion formed by the two tools can join. It is not practical to attempt to blend the cuts on the two tools on a plain surface as it is very hard to set the tools in a correct position because a line or ridge is left where the cuts join. The tools on the back cross slide must not start to cut as soon as the one on the front slide, or the diameter near the chuck will be reduced so that the piece will not be stiff enough to stand forming at its outer end.

In *B* of Fig. 4, the forming tool on the front slide rounds the corner at the top of the screw after the threading operation, and the cutting-off tool forms the end of the next piece while cutting off the one that has been completed. *C* of the illustration is an example

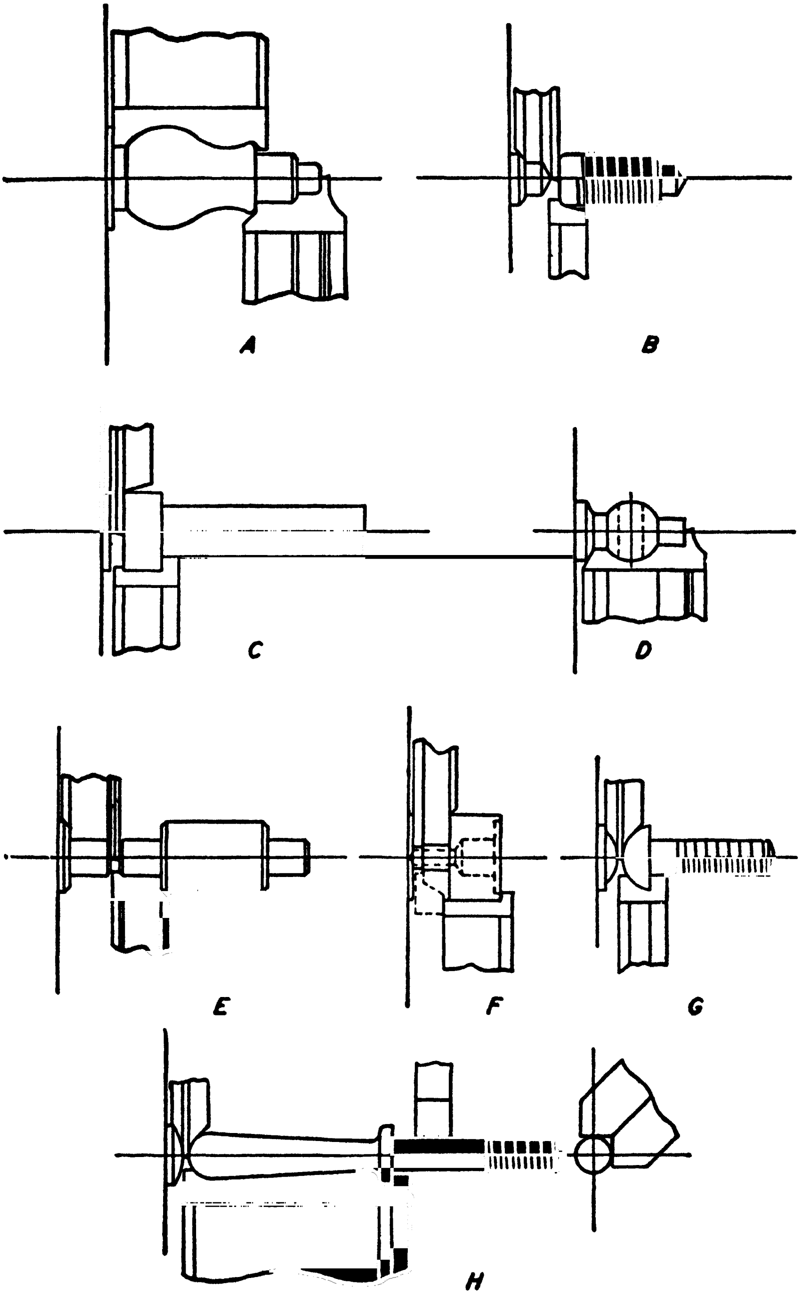


Fig. 4. Examples of Use of Circular Forming and Cutting-Off Tools
Courtesy of Brown & Sharpe Mfg. Co., Providence, R I.

where the forming tools simply square up the head of a piece that has been turned by turret tools. Note that the form tool laps around the back corner of the head to remove any burrs thrown up by the cutting-off tools; both tools operate simultaneously. In *D* all the forming and cutting off is done with the front cross-slide tool, as the rear cross slide carries a cross drilling attachment for putting a hole through the piece at right angles to the axis. *E* of the illustration shows how one end of a piece is finished with the cutoff tool while the other end is produced by the forming tool on the front cross slide after the bar has been fed out.

The piece at *F* has to be made in the manner shown because of internal machining operations required. Both cross-slide tools are used for forming, and the piece is cut off by a swing tool held in the turret and brought into action when the forming is completed. The position of the swing tool when about to cut off the piece is shown by dotted lines. The forming on this piece could not be done by a single tool because the small diameter at the back end of the piece would not be sufficiently strong to support and drive the piece while the tool was cutting on the large diameter. The front form tool removes the burr from the outer end of the piece, and the bevel on the rear form tool removes the burr on the inner corner of the large diameter. On this piece, the form tool on the front cross slide is producing part of the round head and squaring up under the head. The balance of the form of the head is carried on the cutting-off tool, which must be designed and set to blend with the curve produced by the forming tool.

It is customary in making round-headed screw bolts, rivets, and similar pieces, (see *G* of Fig. 4) to design the forming tool so that it will cut around the head to the diameter of the body of the piece, in this way leaving the balance of the head to be formed by the cutting-off tool. When designing the cutting-off tool for such a job, the fact that the piece breaks off before the point of the cutting tool reaches the center must be taken into consideration, and the radius of the tool is set slightly ahead, otherwise the curve will not blend with that of the forming tool.

H illustrates the method of supporting the outer end of a long slender piece. Without the use of this back rest, considerable springing would occur and the finish would not be desirable. These are

but a few of the various types and designs of tools that can be used for producing screw machine parts.

Fig. 5A illustrates a part that is produced by a circular forming tool. This is an illustration of how the difference in the diameters on circular forming tools is calculated. Whenever a circular form tool has two or more diameters, the difference in the radii of the steps on the tool will not correspond exactly to the difference in the steps on the work. This is due to the fact that sufficient periphery clearance on the circular form tools is necessary because the cutting face of the circular form tools is offset in relation to the center of the work.

In Fig. 5A, the example shown, the difference between the small diameter of the work, which is .375, and the next step, which is 655, is .280; whereas the difference between the small diameter of the tool, which is 2.508, and the next step, which is 2.725, is .217. This dimension deducted from .280 leaves a difference of .063, which provides the peripheral clearance. On the work, the dimension of .655 deducted from the largest diameter of the work, .875, is .220; whereas on the circular form tool the large diameter of the tool is 3.000, the second diameter of the tool is 2.725. This is a difference of .275. This makes a difference in diameters between the work and the circular form tool of .055.

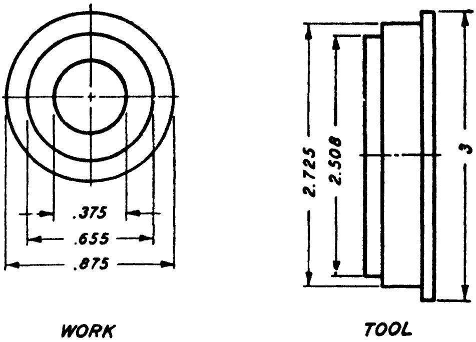


Fig 5A. Example of Work to Show How the Difference in Diameters on a Circular Tool is Calculated

Fig. 5B shows how cross-slide circular tools are mounted in the circular form tool holder for use on automatic screw machines. Holders for circular form tools are described elsewhere in this book.

The design of cutoff tools other than straight thin cutting-off tools is shown by Fig. 6. In this type of tool no top rake is required, and side clearance is only necessary on deep shoulders where rubbing would be objectionable; in this case these tools could be undercut, perhaps one-half degree more or less, depending on the conditions.

In some cases side clearance is objectionable as it provides a place for small chips to collect and load up on the tool, see *A* and *C* of Fig. 6. This can be overcome if the limits will permit a slight taper on the shoulders as shown by *B* and *D*, Fig. 6.

Fig. 7 illustrates various examples of screw machine parts that have been knurled. Knurling tools are furnished in the regular standard forms and patterns. The knurling process consists of forming a series of ridges and diamond-shaped heads on the surface of the work piece by pressure of hardened steel rolls or knurls. This is done on automatic screw machines by having the knurl operate straight in at the side, it being mounted on a round holder that takes the place of a regular circular cross-slide tool. At other times the knurl makes its impression by passing over the top of the piece; in this case it is mounted in a holder that is attached to the circular cutting-off tool. The knurl is located above and ahead of the circular tool so that after it has finished its work on the piece and the cross slide continues to advance, the circular tool comes into action.

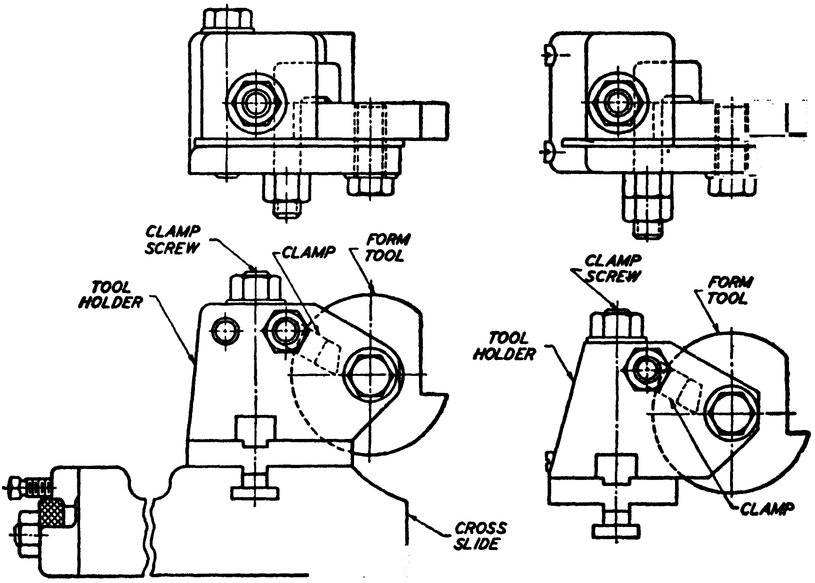


Fig. 5B. Clamping and Adjustment of Cross-Slide Circular Tools

Knurling is also done by feeding into the end of the work, usually with an adjustable knurl holder that carries a pair of straight

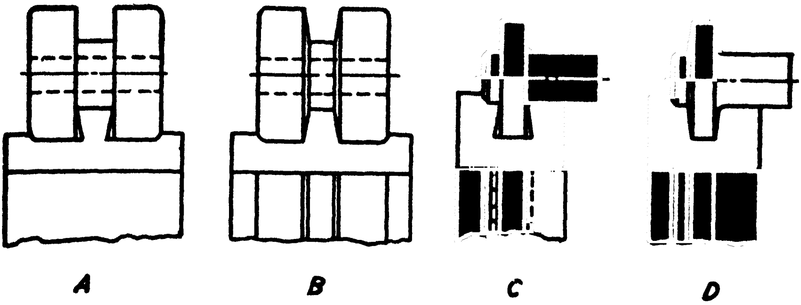
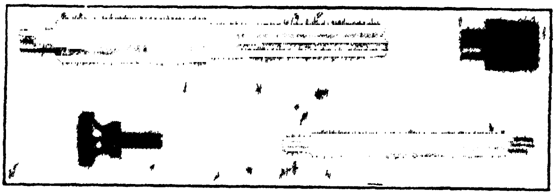
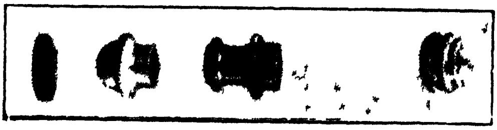


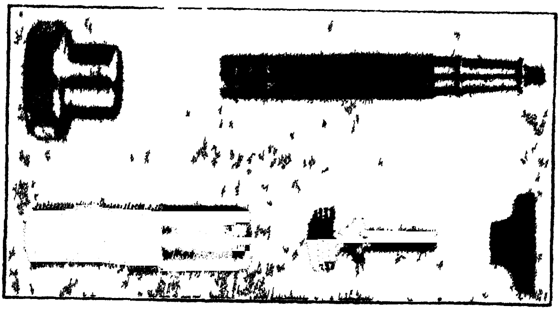
Fig. 6 Illustration of How Loading of Tool Can Be Avoided if Limits of Piece Permit Putting a Slight Taper on the Shoulders



A Examples of Straight Knurling



B Examples of Spiral Knurling



C Examples of Diamond Knurling

Fig 7 Screw Machine Parts Showing Various Types of Knurling
Courtesy of Brown & Sharpe Mfg Co, Providence, R I

knurls. When the knurls are cut parallel to the axis of the work, they produce a straight-knurled surface Fig. 7A; when cut at an angle to the axis, they produce either a spiral-knurled or a diamond-

knurled surface (see Figs. 7B and 7C) depending on whether the knurls are cut at an angle or in opposite directions. In knurling operations it is often necessary to provide some support to prevent the piece from springing away from the knurls.

Fig. 8 illustrates the type and variety of work that can be produced by automatic screw machines. Some of this work can also be done in hand screw machines and in turret lathes. To design tools for automatic screw machine use requires some ingenuity on the part of the tool designer, and considerable knowledge can be obtained by observation of such a machine at work in the plant. The designer should take every opportunity to observe them in operation and use his initiative in developing means and methods for designing and making simple tools, gradually taking up complicated jobs.

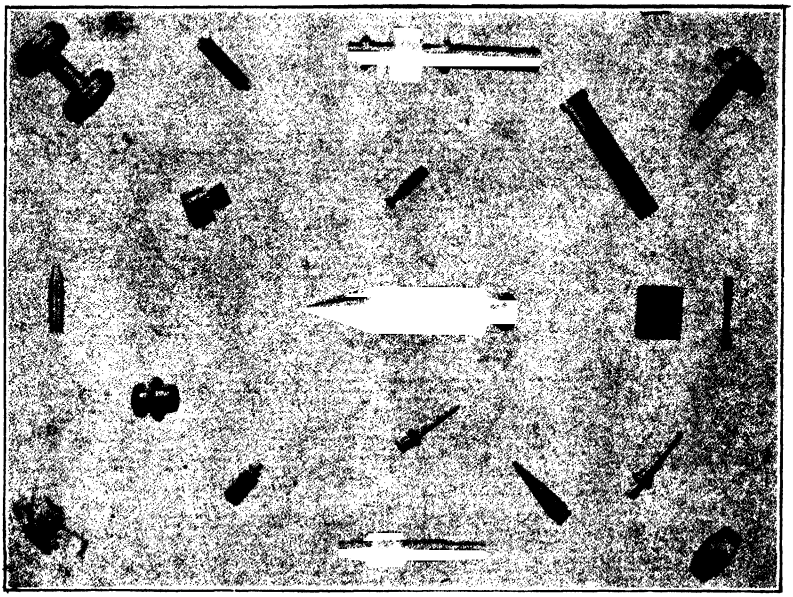


Fig. 8. Parts Produced on an Automatic Screw Machine
Courtesy of Brown & Sharpe Mfg. Co., Providence, R. I.

AUTOMATIC LATHES

Automatic lathes have been developed to a high point of efficiency in order to produce the many parts required by the aviation *and automobile manufacturing companies. These machines are somewhat similar in operation to automatic screw machines and a* great many of the same tools that are used on one machine can be used on the other. Fig. 9 illustrates an automatic lathe tooled to produce a forged part. This setup is machining the shaft end of an automobile steering knuckle such as is shown in Fig. 10, where the rough forged shaft is left, the finished shaft on the right.

These automatic lathes are capable of incorporating numerous operations that are done with comparatively simple tooling.

Fig. 11 shows a close view of a turret setup to bore and counterbore the internal section of a casting, with the cross slide set to machine the face of this casting. Fig. 12 is a photograph of several parts that are capable of being machined in a setup of this kind.

These automatic lathes have builtin electric controls that make work simple for the operator. The rear slides are cam operated, and the cross slides are also operated by means of cams. These machines are all equipped with coolant pumps so that, in machining steel or other metals that would require coolant to the point of the cutting tools, it can be provided readily. The cross slides can be operated simultaneously or independently. Work on many of the high-production parts of today is done in machines of this kind, as the tooling for them is comparatively simple and inexpensive.

For the production of shells and other munitions that are needed in large quantities in times of emergency, these automatic lathes are capable of performing a great many operations that would be rather difficult in other types of machines. Fig. 13 is a photograph showing a 75 mm. shell body. The lower view shows the copper rotating band, that engages the rifling grooves in the gun, shrunk in place on the body of the shell. This operation is done by means of a press that has a die equipped with staking punches. These punches force the copper rotating band into the recess that has been machined in the body of the shell. The upper view shows the copper rotating band after being roughed, finished, turned, formed and chamfered.

Fig. 14 is a photograph showing a closeup view of the tooling required to perform these various operations. You will note the arrangement of the tool bits, particularly the way they are mounted on the cross slides of this machine. Note the swinging adjustable stop which properly locates the shell in the air-operated collet type

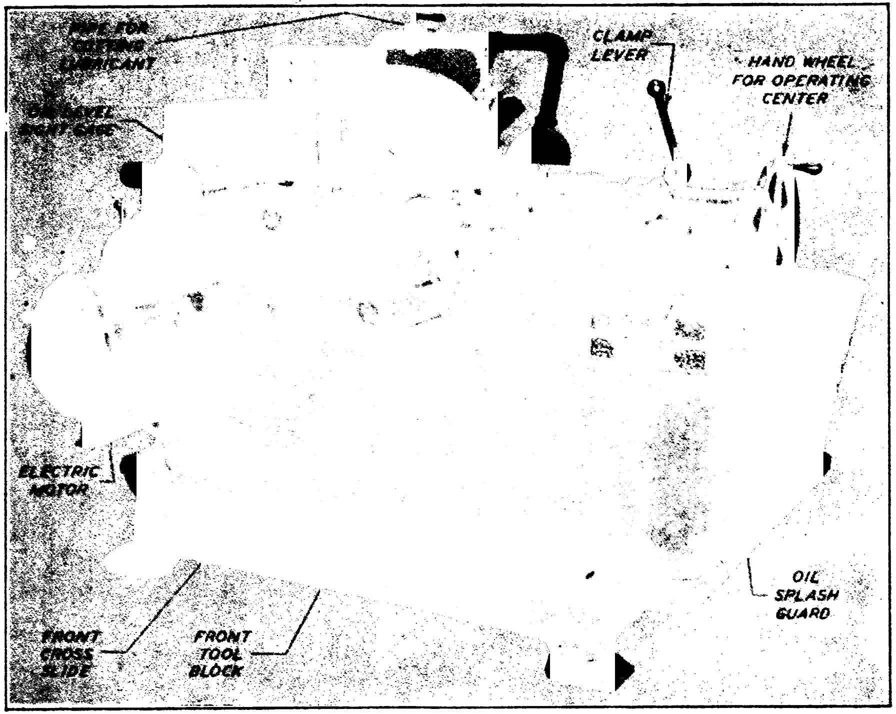


Fig. 9. Automatic Lathe
Courtesy of Sundstrand Machine Tool Co., Rockford, Ill.

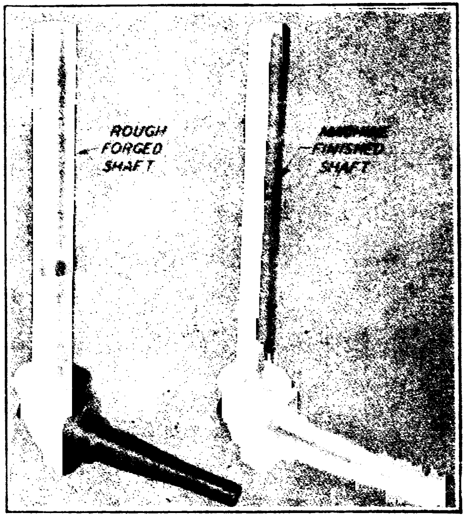


Fig. 10. Automobile Steering Knuckles Showing Rough-Forged and Finished Shafts
Courtesy of Sundstrand Machine Tool Co., Rockford, Ill.

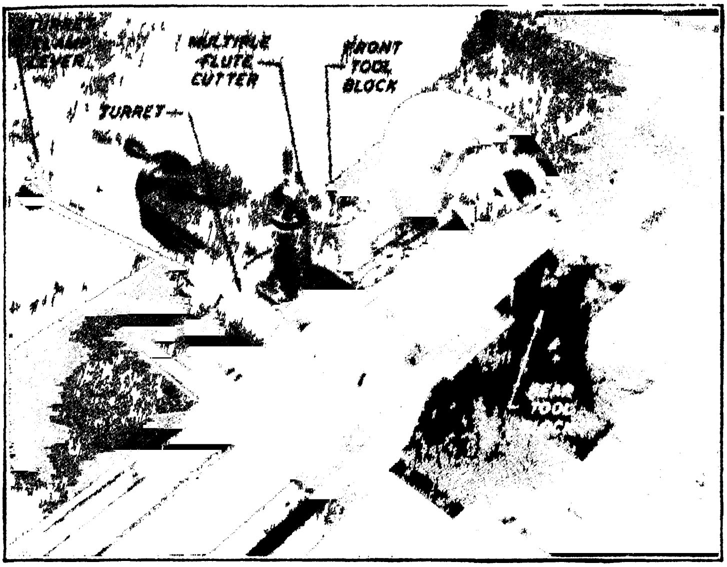


Fig 11. Turret Setup to Bore and Counterbore the Internal Section of a Casting Cross Slide Is Set to Machine the Face of the Casting

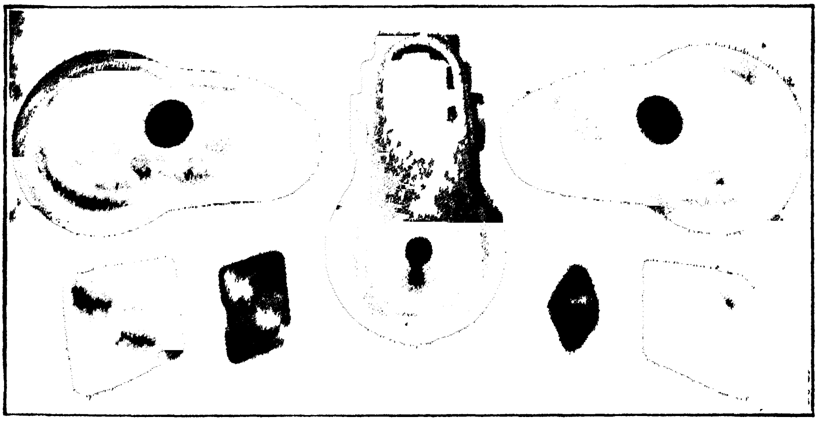


Fig 12 Typical Piece Parts which Can Be Machined in a Setup Such as Is Shown in Fig 11

Courtesy of Sundstrand Machine Tool Co , Rockford, Ill

chuck. This insures that the shell is in correct position for the machining operations The tooling consists of two cemented carbide tools on the front tool side; one is used to rough turn the outside diameter, the other is to finish turn the outside diameter. The travel of the feed on these tools is from right to left The two cemented

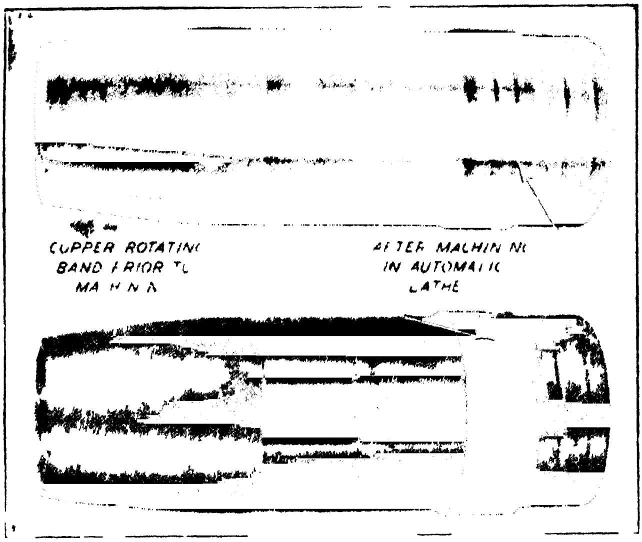


Fig 13 75 MM Shell Forging
Courtesy of Sundstrand Machine Tool Co Rockford Ill

carbide tools on the rear tool slide are set so that one is to rough form and chamfer the outside diameter, the other tool is to finish form and chamfer the outside diameter

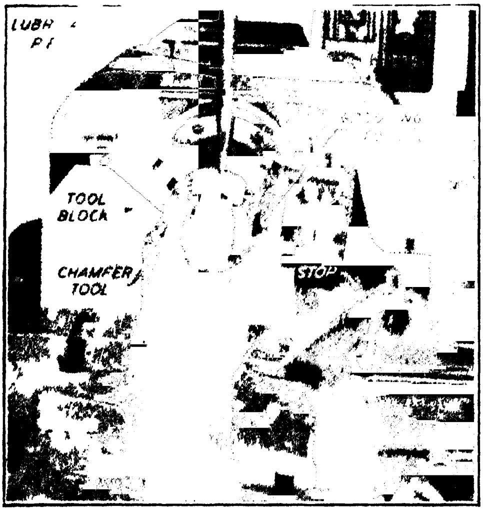


Fig. 14. Tooling Required to Perform Necessary Operations on Piece Part Shown in Fig 13
Courtesy of Sundstrand Machine Tool Co , Rockford, Ill

Fig 15 is a drawing showing the tooling layout for this job The air-operated collet type chuck has a spring-loaded cup center that permits the rapid location of the shell body in the chuck The spring pushes the shell body toward the swing type end stop After this, the air valve is thrown on and the chuck automatically locks the shell body in the collet chuck. Machining operations follow. Production per hour is about 120

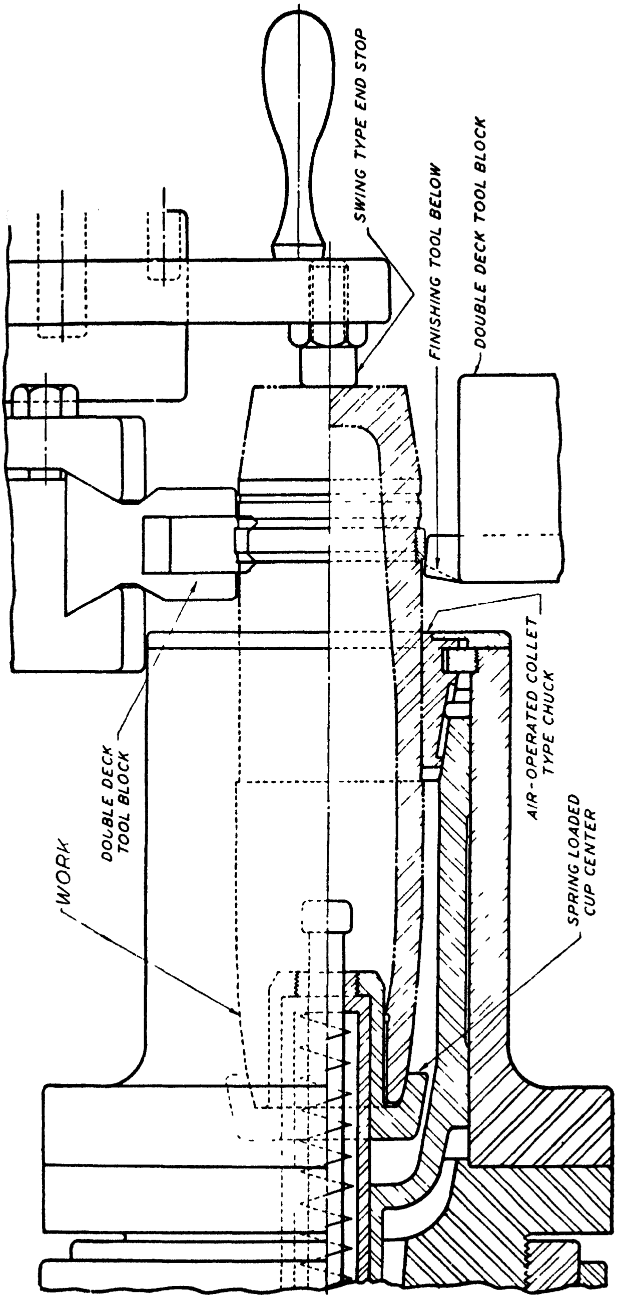


Fig. 15. Tooling Layout for Machining the Piece Part Shown in Fig. 13.

Tractor parts such as shown by Fig. 16 can all be produced in a setup on the cross slides of one of these automatic lathes. Fig. 17 shows tool blocks with individual square tool bits mounted in them for turning the rear stub axle of a tractor. Note the design of these tool blocks. Square tool bits are mounted in a block that has the proper width of groove cut in it, and then a cover plate is used that fastens to the lower block by means of hexagon head cap screws. Hollow-head setscrews and square-head setscrews are used for locking the tool bits in place in the tool blocks. The adjustment and backup of these tool bits is accomplished by means of hollow-head screws

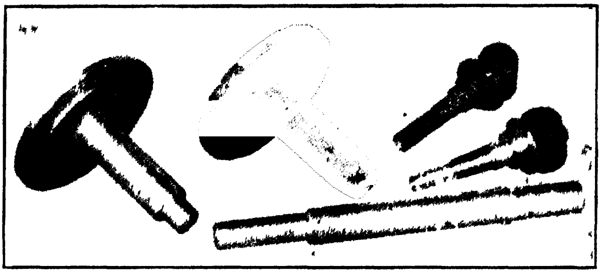


Fig 16 Steel Forgings for Tractor Parts
Courtesy of Sundstrand Machine Tool Co, Rockford, Ill

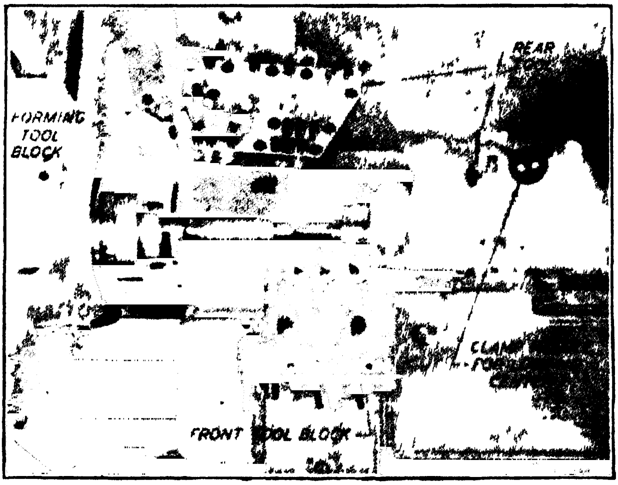


Fig 17. Tool Blocks in which Individual Square Tool Bits Are Mounted
Courtesy of Sundstrand Machine Tool Co, Rockford, Ill.

that can be moved in or out to suit the needs of the jobs. Tool blocks for jobs of this kind are similar in design to those that are used in turret lathes.

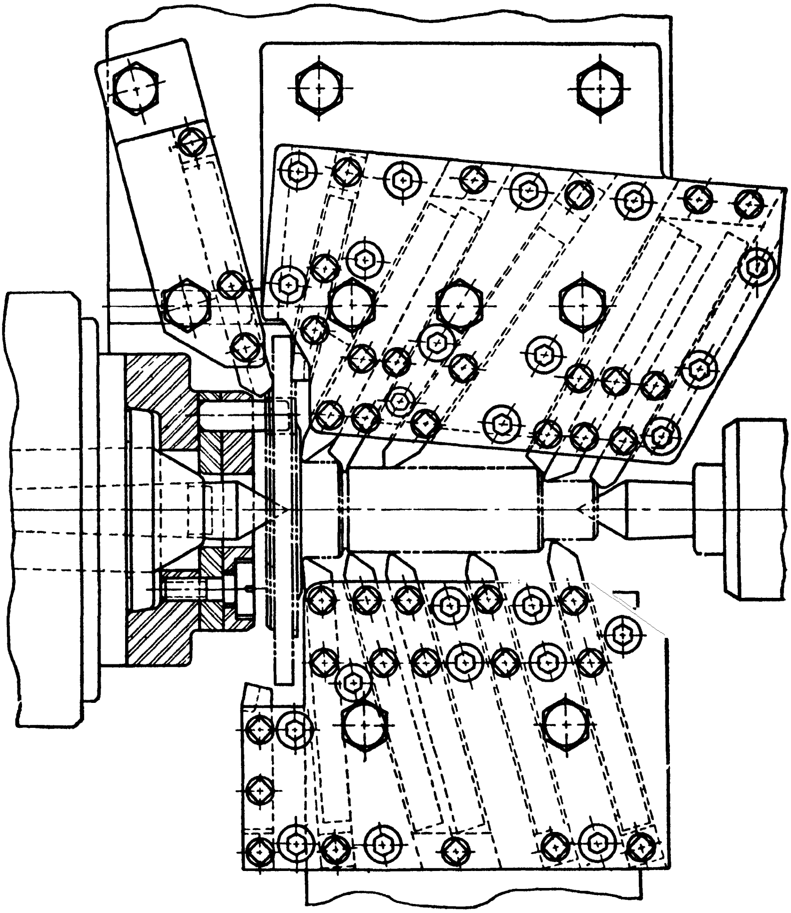


Fig. 18. Design and Construction of Tool Blocks Shown in Fig. 17

Fig. 18 is a drawing showing the design and construction of these tool blocks. This design is very simple and the tool blocks can be varied according to the requirements of the piece part.

In manufacturing bicycles it is necessary that a great many of these parts be produced as cheaply as possible, and at the same time accuracy is essential. Bicycle wheel hubs are required in large quantities Fig 19 shows the rough forgings and the finished hub. This job is ideal for an automatic lathe.

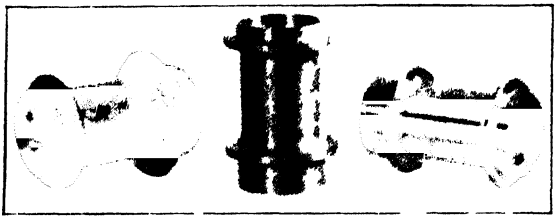


Fig 19 Bicycle Wheel Hubs. Rough Forgings and a Finished Hub

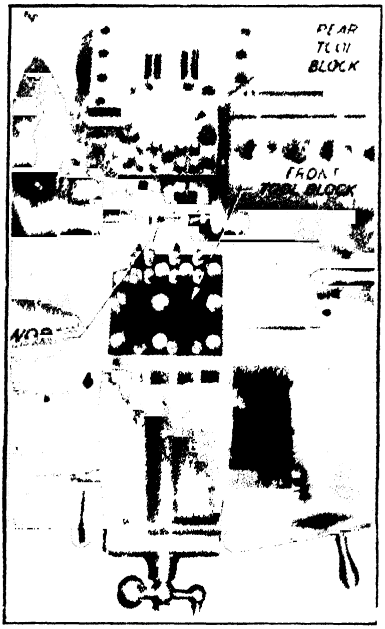


Fig 20 Tool Setup Showing the Roughing Operation Being Performed on a Bicycle Hub

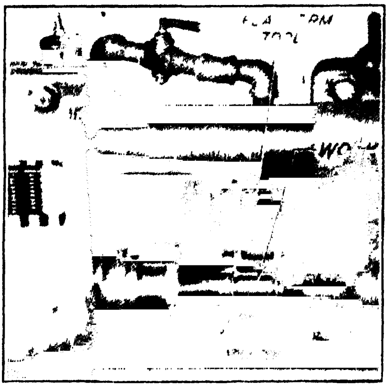


Fig 21. Finishing Operation Being Performed on a Bicycle Hub

Courtesy of Sundstrand Machine Tool Co, Rockford, Ill

Fig. 20 shows the rough forging in place between centers, with the two tool blocks that contain the necessary tool bits for the roughing operation. This removes all excess stock and brings this bicycle hub to the required finishing dimensions.

Fig. 21 shows the finishing operation being done by a dovetail

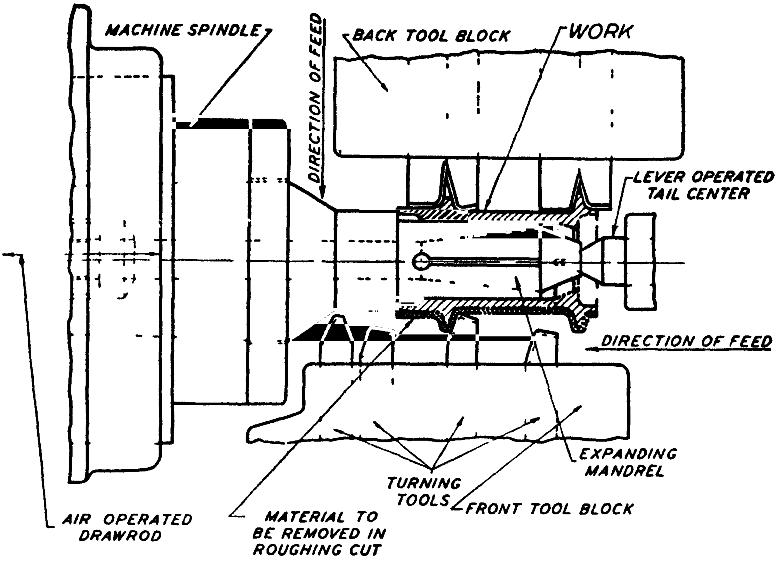


Fig 22 Layout for Rough Turning and Forming a Bicycle Hub

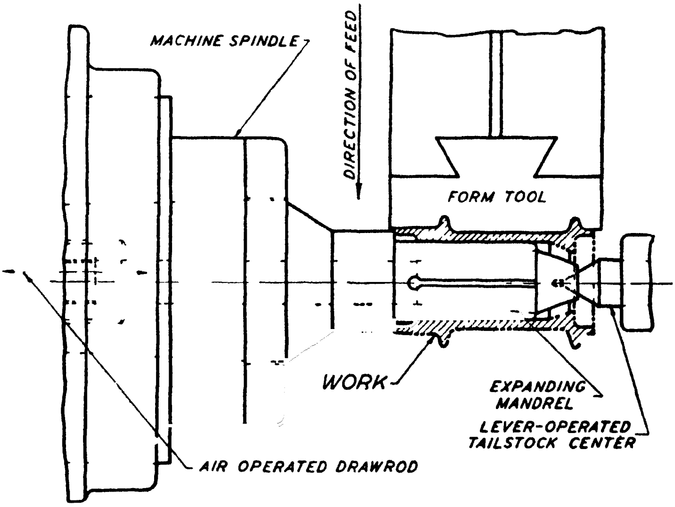


Fig 23 Layout for the Finishing Operation on a Bicycle Hub

flat form tool This takes all dimensions at one time and insures all points being in definite relation to each other.

Fig. 22 is a drawing showing a layout of the tool in the tool block for the roughing operation. The driving mechanism for this hub is an air-operated expanding mandrel that is actuated by means of a draw rod. This rod operating within the mandrel is tapered to suit the corresponding taper on the mandrel. The mandrel is split and is similar to a collet chuck. It permits the mandrel to expand against the internal bore of the bicycle hub, thereby providing a means for driving this hub. As you will note from the drawing, there would be no way of fastening an ordinary driver to the outside diameter of this bicycle hub, as all sections of this hub are finished. The production per hour with a tool setup of this kind is approximately 48 pieces.

Fig. 23 shows a layout of the tooling for the finishing operation. You will note that in this drawing the dovetail forming tool is mounted on the rear slide and the same air-operated expanding mandrel is used for this finishing operation. The forming tool mounted in the rear slide cuts against the rotation of the work. These flat forming tools are similar to circular forming tools; that is, they are ground on the cutting face only and do not change their form due to grinding. These tools can be designed to meet the needs of most jobs; however, there are limits to the length of work this type of flat forming tool can be designed to do.

The inner races for automobile universal joints present a rather difficult machining operation. Fig. 24 shows that this piece is machined all over. The part is drilled and reamed, then the splines are broached. The outside diameter is then turned to a radius, then the grooves on the outside diameter must be machined. These in turn are machined to a radius, as will be observed from the illustration.

Fig. 25 illustrates a tooling setup for machining the radii in the outside diameter of these races. One high-speed steel circular forming tool is mounted on the rear tool slide to rough-form the radii. To finish these radii, a high-speed circular forming tool is mounted on the front tool slide. The piece part is located in the spindle of the machine by means of a center and a compensating driver. This tooling layout is shown by Fig. 26. The other end of the piece is located by a center in the rear slide of the machine. The production per hour on a job of this kind is 39 grooves, or 13 pieces. This type of work would be difficult to produce on any other type of machine at a comparable cost.

An automatic lathe is the ideal tool to produce certain parts for the aeronautics industry where limits of accuracy have to be held extremely close and all dimensions are in definite relation to each other. Such a part, an aeroplane hydromatic propeller pilot valve housing, is shown by Fig. 27. All roughing operations can be accomplished at one setup by means of properly designed tools. The finishing operations can then be performed by one additional setup

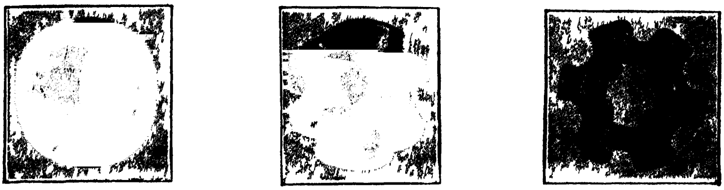


Fig 24. Rough and Finished Machined Inner Races for Universal Joints. Left, Rough Machined, Center, Semifinished Right, Finished

Fig 25 Tooling Setup for Machining the Radii in the Outside Diameter of the Piece Part Shown in Fig 24

Courtesy of Sundstrand Machine Tool Co , Rockford, Ill to obtain the required limits of accuracy; whereas if the job had to be done in an engine lathe there would be constant changing of tools

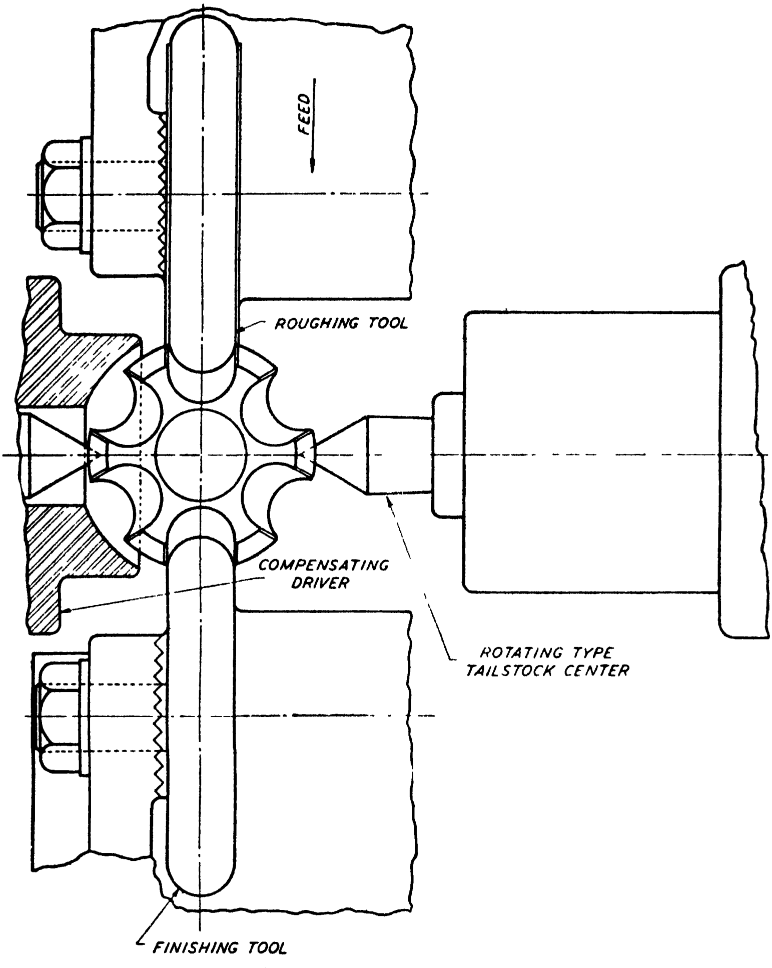


Fig. 26. Tooling Layout for the Operation Shown in Fig. 25

and it would require considerable time on the part of the operator to check the various dimensions, or a large number of gages would have to be provided to see that these parts were to the limits required.

Fig. 28 shows a layout of the tool blocks on the front and rear slides of an automatic lathe that completely finishes this part at one setup. This tooling consists of six high-speed steel tools carried on

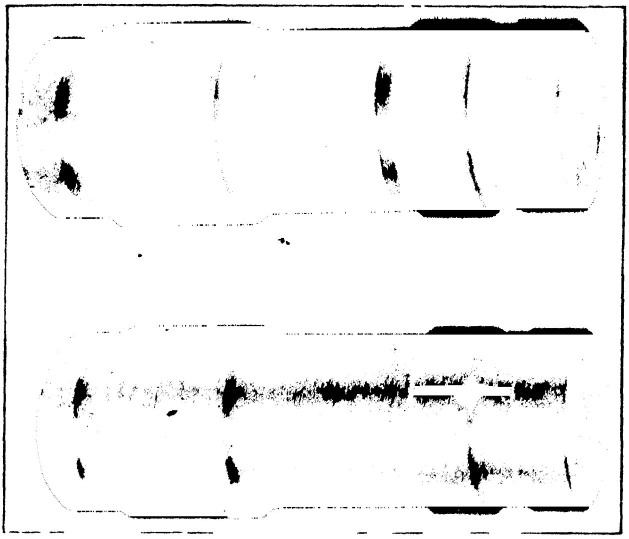


Fig 27 Machined Aeroplane Hydromatic Propeller Pilot Valve Housing Above, Rough, Below, Finished

Courtesy of Sundstrand Machine Tool Co Rockford Ill

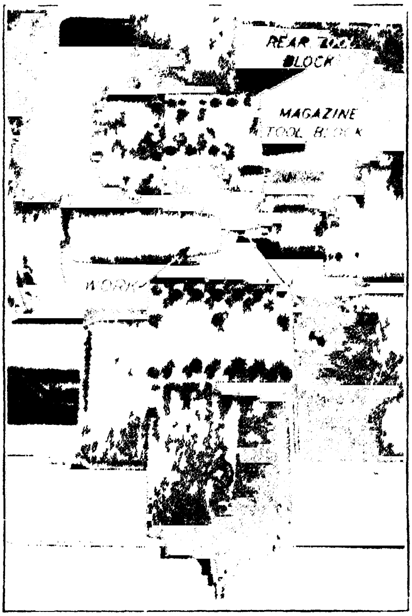


Fig 28 Layout of Front and Rear Tool Blocks to Finish Piece Part Shown in Fig 27 at One Setup

Courtesy of Sundstrand Machine Tool Co, Rockford, Ill

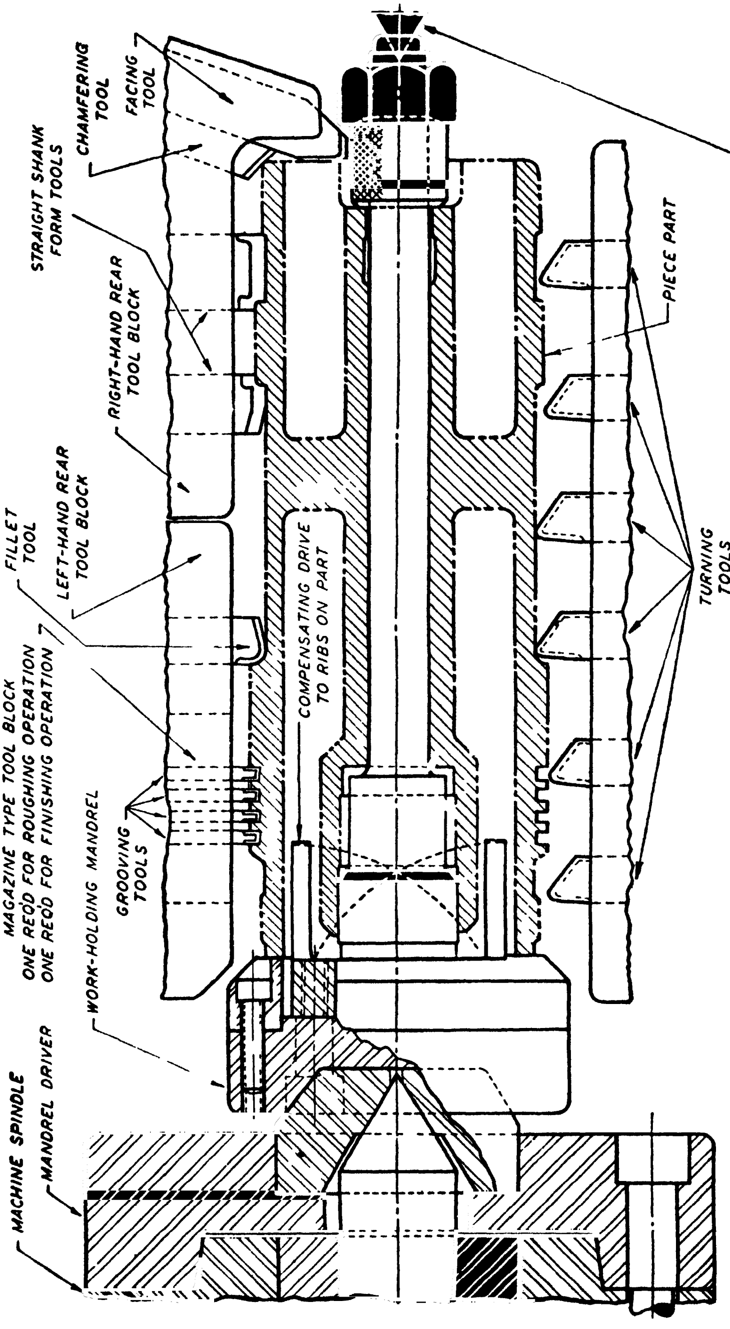

MACHINE SPINDLE
MANDREL DRIVER
WORK-HOLDING MANDREL
MAGAZINE TYPE TOOL BLOCK
ONE REQ'D FOR ROUGHING OPERATION
ONE REQ'D FOR FINISHING OPERATION
GROOVING TOOLS
FILLET TOOL
LEFT-HAND REAR TOOL BLOCK
RIGHT-HAND REAR TOOL BLOCK
STRAIGHT SHANK FORM TOOLS
CHAMFERING TOOL
FACING TOOL
COMPENSATING DRIVE TO RIBS ON PART
PIECE PART
TURNING TOOLS
BALL-BEARING TAIL CENTER

Fig. 29. Layout of the Usual Setup for Producing the Piece Part Shown in Fig. 27

the front tool slide to turn four diameters. The feed travel on this slide is from right to left. One high-speed steel facing tool is carried in the right-hand rear tool block to face the right-hand end to the proper length, and one high-speed steel chamfering tool is carried in the right-hand rear tool block to chamfer the right-hand corner. There are two high-speed steel straight shank form tools carried in the right-hand rear tool block to form two sections of this part. Then in the other tool block, mounted on the rear cross slide, are four high-speed steel grooving tools carried in a magazine tool block, which in turn is located in the left-hand rear tool block to machine the four grooves required on this piece. This is a good example of what proper designing of tools can accomplish for a part of this kind. Other similar parts can be tooled in the same manner. The magazine type tool block, as specified, consists of a three-sided section of steel, similar to a box without ends, so that the grooving or cutting-off tools can be mounted with the proper spacers and inserted in the block itself as a unit.

Fig. 29 is a layout showing the usual setup for producing this part. The arrangement of the various tools is clearly shown and this part is mounted on a mandrel that has fingers extending from it to the driver to rotate the work. These fingers are located in ribs on the part.

CHUCKS AND CHUCK JAWS FOR TURRET LATHES AND AUTOMATIC LATHES

The use of chucks on automatic lathes, drill presses, planers, boring mills, and turret lathes has increased during the past few years to a point where it would be almost impossible to design tools for some of these machines without using chucks and standard and special chuck jaws.

A chuck is a device for holding the work or tools securely and rigidly so as to permit various machining operations. There are various types and classes of chucks and, in addition to the machine tools already mentioned, there are various types of special machines to which chucks can be adapted and used.

Tool-holding chucks are those used for holding drills, reamers, taps, and special multiple-operation tools.

Independent Chucks. This is a chuck in which each individual jaw for holding work is moved in or out across the face of the chuck body by means of a screw. These chucks may have two or more jaws, depending on the size of the chuck and the size of the work piece to be held. The usual type of independent chuck is made with four jaws so that almost any type of work piece of irregular shape or form may be held securely.

Self-centering Chucks. This type of chuck has two, three, or four jaws that are operated simultaneously by means of a scroll located in the body of the chuck and operated by a screw or by means of a rack gear and screws.

Combination Chucks. A chuck of this type combines the features of both the independent and self-centering chucks. The jaws to hold the work may be moved to or away from the work piece as in an independent chuck, or moved to and from the work piece by means of a scroll and pinion, or by means of rack gears and pinion screw, and when they are moved will maintain a common center. This type of chuck may have either three or four jaws and is intended for use in holding work pieces of any irregular shape or outline.

Face Plate Boring-Mill Jaws. This is a self contained jaw mounted in a body in which are fitted thrust bearings and operating screws for moving the jaw to and away from the piece of work. These bodies are designed so they can be attached to face plates and tables of boring mills, planers or planer type milling machines.

Power Chucks. On large pieces of work which are handled by means of a crane, power chucks are used. In some cases this type of chuck is used where it is necessary to grip the work very tightly; power chucks are found to be less fatiguing than manually operated chucks. Power chucks are operated by air, hydraulically, or by electric motor. The power element is mounted with a suitable adapter on the spindle or is self-contained within the machine. A drawbar within the machine spindle has one end designed to be connected to the power element, while the other end is connected to the chuck jaw-operating means.

All chuck backs are designed so that suitable means can be provided for attaching them to the various machines on which they are to be used.

Chuck Body. This is the part in which the operating means or mechanism is contained and on which are jaws which may be moved in or out for holding the work piece

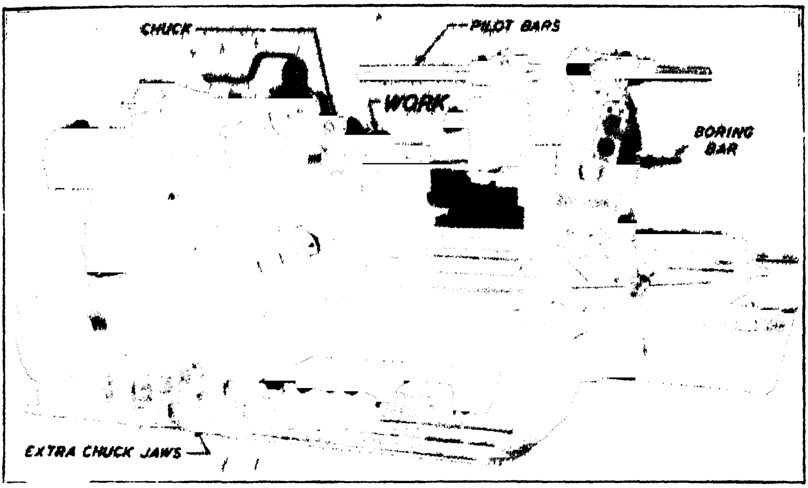


Fig 30 **Turret Lathe Completely Tooled for a Variety of Work**
Courtesy of Foster Machine Co Elkhart Ind

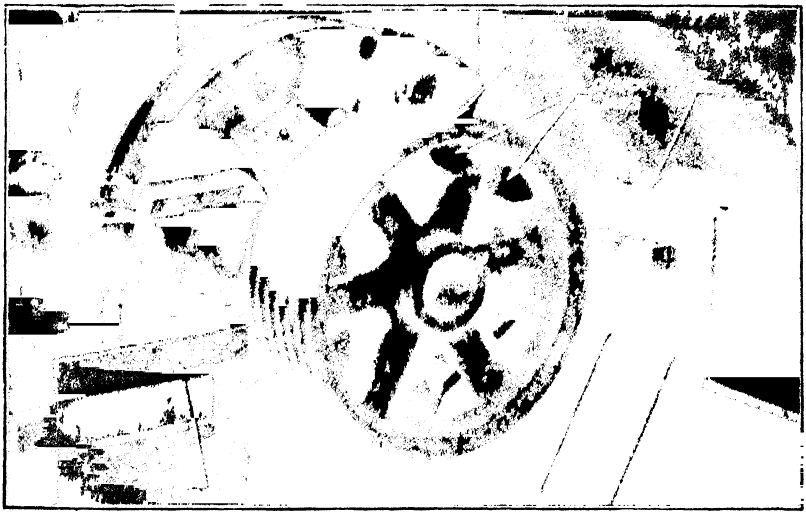


Fig 31 **Close-up View of Turret Lathe Tooled for Machining V-Belt Pulley**
Courtesy of Foster Machine Co Elkhart Ind

Body Front This is the part which carries the jaws when the body is designed and made of more than one piece or section

Body Back. This is the section of a chuck which encloses the jaw-operating means and is designed to fit the machine spindle.

Chuck Jaws. Standard jaws are suitable for holding a great variety of types of work, but in many instances special jaws are necessary. The tool designer in designing jaws must take into consideration the type of chuck available, the design of the work to be chucked, and whether the piece can be gripped on the outside or whether it is necessary to design the chuck jaws so that the gripping action will take place on the internal section of the work piece.

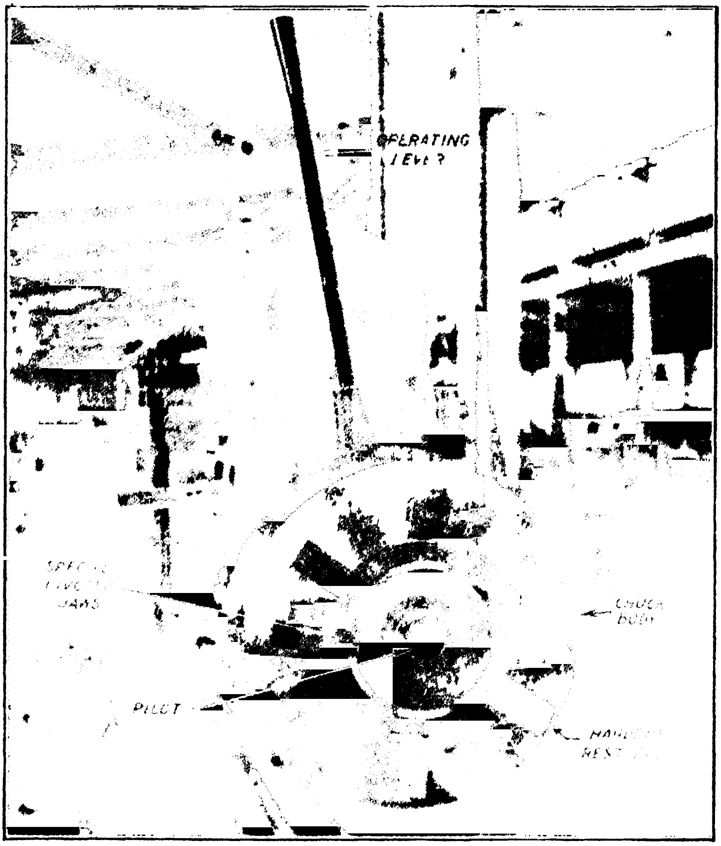


Fig 32 Wrenchless Chuck
Courtesy of Foster Machine Co, Elkhart, Ind

Outside Step Jaws. These jaws are designed to hold the work pieces by gripping on the outside only. The design is such that the jaws cannot be reversed. This type of jaw is highest at the outside diameter of the chuck body.

Inside Step Jaws. This type of jaw is designed to hold the work by gripping the inside only. This jaw is highest at the center of the body of a chuck and is designed so that it will also hold rods or shafts that are inserted through the center hole of a chuck body. This jaw cannot be reversed in the chuck.

Jaws are designed for various chucks so that they can readily be mounted on a master jaw contained in the chuck body. These special chuck jaws can be designed and made so that they will fit the needs of the particular job they are intended for. Some of these jaws are made with the gripping surface serrated to hold the work more securely. Inside step jaws are usually hardened and ground.

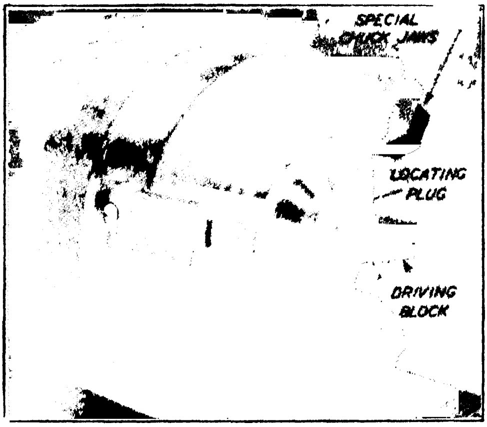


Fig 33 Chuck Adapted to Turning Automobile Axle Housings

Courtesy of Foster Machine Co , Elkhart Ind

Sizes of Standard Chucks. Chucks for automatic lathes, milling machines, boring mills and turret lathes are regularly furnished as standard in the following sizes: 6, 8, 10, 12, 15, 18, 21, 24, 28, 32, and 36 inches. The outside body diameter of a chuck is in accordance with the size of the chuck in inches with the exception of the 6-inch size which is 6½ inches, and the 8-inch size has a body diameter of 8¼ inches. The tool designer can readily adapt chucks to hold work pieces of almost any shape. It is very inexpensive tooling because, once a chuck has been purchased, various types of jaws can be designed and made for holding a great variety of work.

Fig. 30 illustrates a turret lathe completely tooled. It is equipped with a chuck and jaws for machining a **V**-belt pulley. This turret lathe is also used for a number of other jobs, and a group of these chuck jaws is shown immediately in front of this machine. This is a good illustration of the wide adaptability of chucks for use on machines of this type. This same type of chuck can be used readily on an ordinary engine lathe

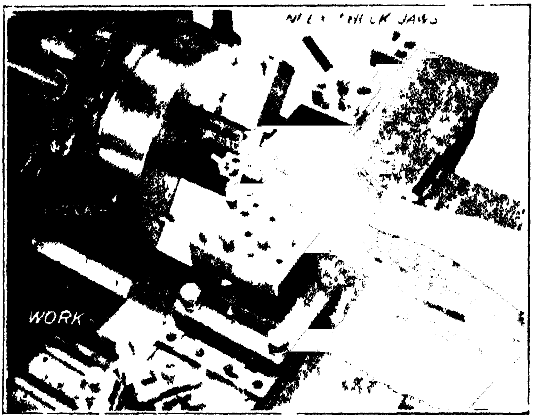


Fig. 31 Index Chuck for Machining Differential Spiders
Courtesy of Foster Machine Co., Elkhart, Ind.

Fig. 31 is a close-up view of the chuck and the arrangement of jaws for gripping a **V**-belt pulley or sheave. Note that these jaws, which are three in number, grip the work on the inside. The face of each chuck jaw is serrated and a slot is cut into each jaw to permit the arms of the pulley to clear. Also, these jaws were relieved in this manner to permit the work to be located as near the face of the chuck as possible; this is to prevent any unnecessary springing and to reduce overhang.

For certain types of jobs a wrenchless chuck is frequently used. This allows fast operation and it is only necessary for the operator to pull the lever down to lock the chuck jaws in position and grip work securely; to release jaws, push lever in opposite direction.

Fig. 32 illustrates a wrenchless chuck with three equalizing jaws for gripping truck wheels on a second operation. *The rear side of the truck wheel was bored and faced in a previous operation.* This

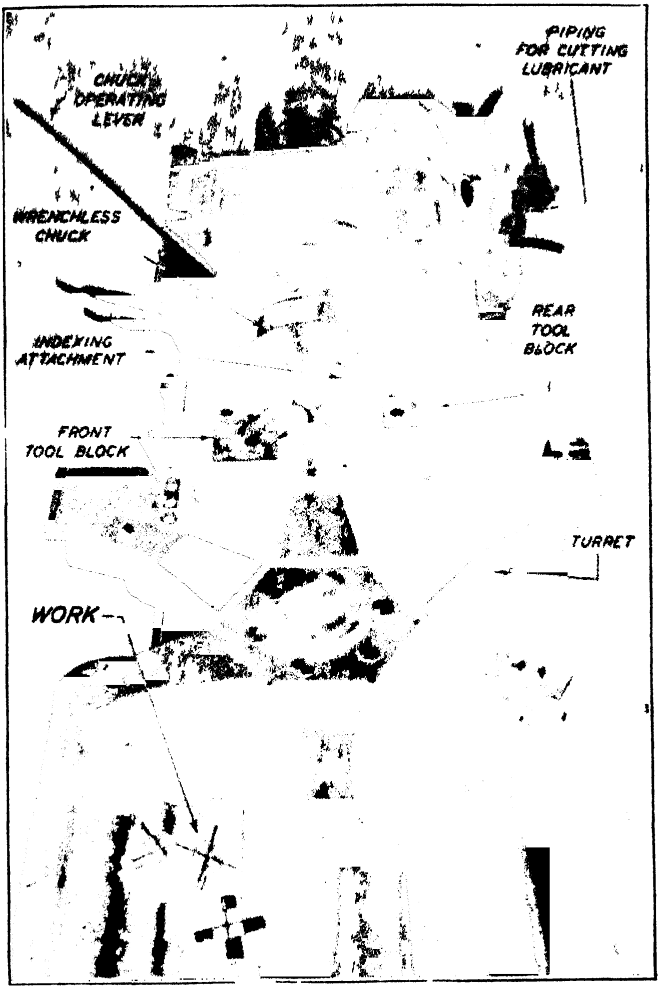


Fig. 35 Close-up View of Tooling on Turret Lathe for Machining Differential Spiders

Courtesy of Foster Machine Co Elkhart Ind

means that the wheel must be chucked so that the machining on the second operation is in perfect alignment with the previously machined surfaces. The wheel is located on a pilot mounted on the central portion of the chuck. The jaw pressure is equalized by means of a floating ring which makes it possible for the jaws to grip on a rough or unfinished surface Note the tapered pilot for locating the wheel The design of jaw shown here illustrates the versatility of chucks of this type

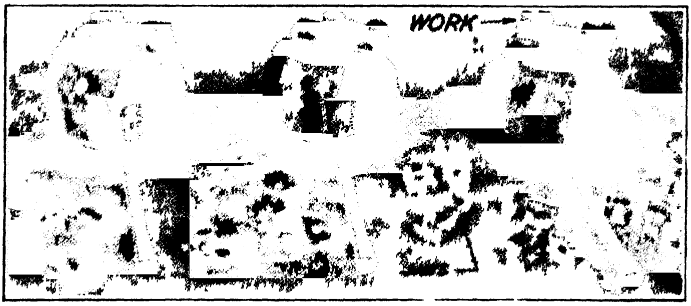


Fig 36 Wrenchless Chucks Equipped with Special Jaws These Chucks Are Used in Drilling Operations

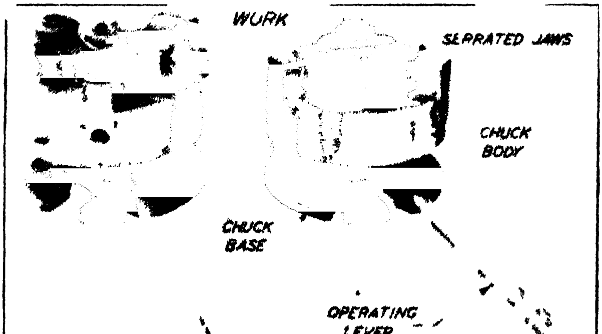
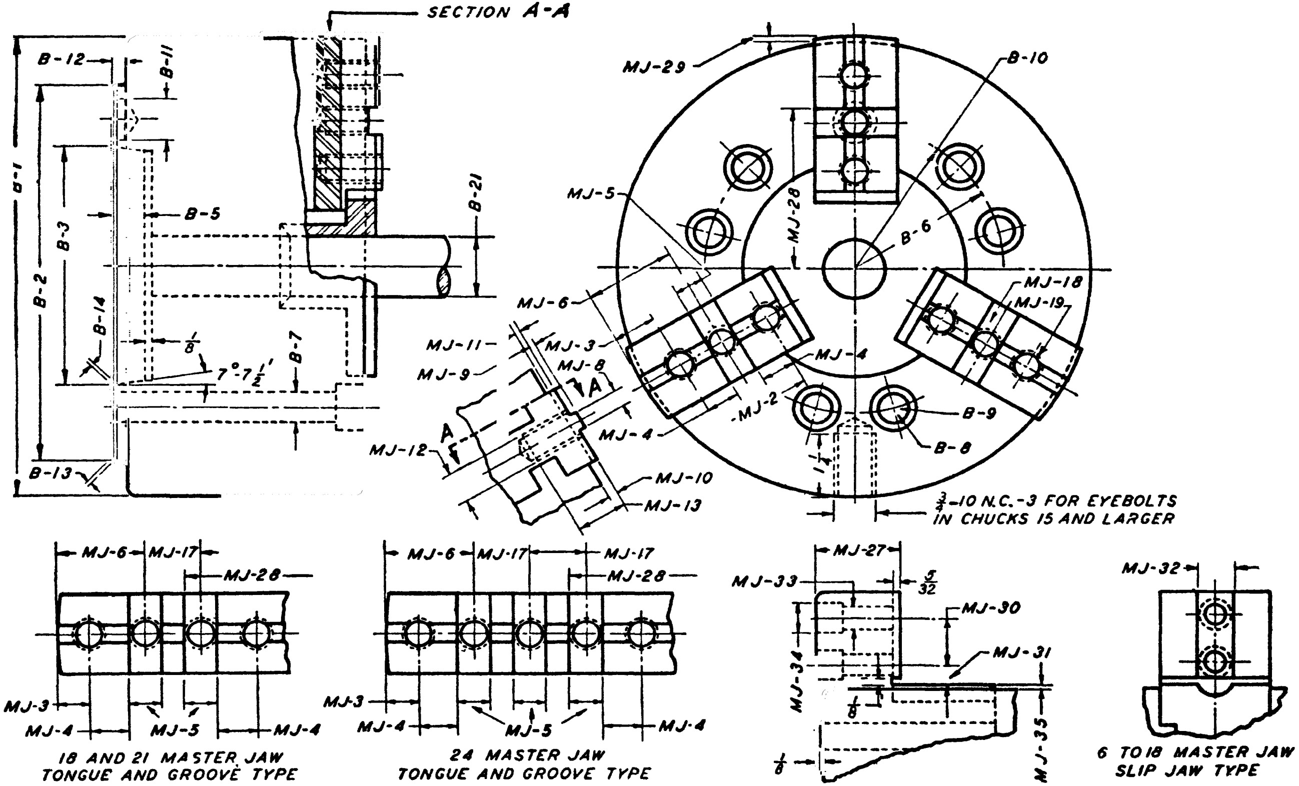


Fig 37 Wrenchless Chucks with Special Jaws for Holding Parts of Irregular Shape For Drilling or Milling Operations

Courtesy of Foster Machine Co Elkhart Ind

For machining automobile axle housings, a chuck designed similar to Fig 33 can be used This chuck is also equipped with equalizing jaws, and note that these jaws are pivoted so as to permit the work itself to act as a centering device When pressure is applied on the jaws, they grip the work evenly and hold it securely in position for the machining operations

On special automatic machines that are used for producing work in large quantities (such as differential spiders for tractor



18 AND 21 MASTER JAW TONGUE AND GROOVE TYPE

24 MASTER JAW TONGUE AND GROOVE TYPE

6 TO 18 MASTER JAW SLIP JAW TYPE

Fig. 38A. Design for Tongue-and-Groove Type Power-Operated Chucks for Turret and Automatic Lathes

Tongue-and-Groove Type, Power-Operated Chucks for Turret and Automatic Lathes

Body

Size of chuck, in	6	8	10	12	15	18	21	24
B-1 Diam of body in	6 1/2	8 1/4	10	12	15	18	21	24
B-2 Diam of flange in	5 3/4	7 1/8	8 7/8	8 7/8	11 3/4	11 3/4	15 7/8	15 7/8
B-3 Pilot diam , in	3 250 − 0005	4 1875 − 0005	5 500 − 0005	5 500 − 0005	7 750 − 0005	7 750 − 0005	11 250 − 001	11 250 − 001
B-5 Depth of pilot hole, in	1/2	9/16	5/8	5/8	11/16	11/16	3/4	3/4
B-6 Radius of bolt circle, in	2 1/16 ± 006	2 5/8 ± 006	3 3/8 ± 006	3 3/8 ± 006	4 5/8 ± 008	4 5/8 ± 008	6 1/2 ± 008	6 1/2 ± 008
B-7 Drill size for bolts, in	13/32	1/32	21/32	21/32	51/64	51/64	59/64	59/64
B-8 Bolt numbers, 3-jaw	1 2-5-6-9-10	1 2-5-6-9-10	1 2 5-6-9-10	1 2 5 6-9-10	1 2-5-6-9-10	1 2-5-6-9-10	2-3-6-7-10-11	2-3-6-7-10-11
B-9 Bolt numbers 2-jaw	1 3 5 7 9 11	1 3 5-7 9-11	1 3-5-7-9 11	1 3-5-7 9-11	1-3 5-7-9-11	1 3-5-7-9-11	1 3-5-7-9-11	1-3-5-7-9-11
B-10 Radius of drive button hole in	2 1/16 ± 003	2 5/8 ± 003	3 3/8 ± 003	3 3/8 ± 003	4 5/8 ± 006	4 5/8 ± 006	6 1/2 ± 006	6 1/2 ± 006
B-11 Diam of drive button hole in	41/64 + 004	43/64 + 004	6[illegible]/64 + 004	6[illegible]/64 + 004	1 5/32 + 004	1 5/32 + 004	1 13/32 + 004	1 13/32 + 004
B-12 Depth of drive button hole in	1/4	1/4	5/16	5/16	3/8	3/8	3/8	3/8
B 13 Chamfer, in	1/32	1/16	1/16	1/16	1/16	1/16	1/8	1/8
B 14 Chamfer in	1/16	1/16	1/16	1/16	1/16	1/16	1/8	1/8
B-21 Pilot bar diam in	13/16	1 1/8	1 1/2	1 3/4	2	2 1/2	3	3

Master Jaw, Slip-Jaw Type

Size of chuck in	6	8	10	12	15	18	21	24
MJ-27 Length of horn, in	1 1/2	1 1/2	1 1/2	2	2 1/2	3		
MJ-30 Center to center bolt holes in	7/8	7/8	7/8	2	2	2		
MJ-31 Bolt center to face of jaw in	3/8	3/8	3/8	[illegible]/16	[illegible]/16	7/16		
MJ-32 Width of tongue slot in	625 − 001	625 − 001	625 − 001	750 − 001	750 − 001	750 − 001		
MJ-33 Drill size for bolts in	2[illegible]/64	2[illegible]/64	[illegible]/64	33/64	33/64	33/64		
MJ-34 C bore for bolt head in	3[illegible]/64	3[illegible]/64	37/64	49/64	49/64	49/64		
MJ-35 Face of jaw to face of chuck in	1/16	1/16	1/16	1/8	1/8	1/8		

Master Jaw, Tongue-and-Groove Type

Size of chuck, in	6	8	10	12	15	18	21	24
MJ-2 Center to center bolt holes in	1 1/2	1 3/4	2 1/8	1 1/4	1 1/2	1 1/2	1 1/2	1 1/2
MJ-3 Bolt center to outside edge in	[illegible]/16	9/16	5/8	3/4	7/8	7/8	7/8	7/8
MJ-4 Bolt center to key slot edge in	1/2	5/8	11/16	7/8	1 1/8	1 1/8	1 1/8	1 1/8
MJ-5 Width of cross slot key in	500 − 001	500 − 001	750 − 001	750 − 001	750 − 001	750 − 001	750 − 001	750 − 001
MJ-6 Outside edge to key slot center in	1 3/16	1 7/16	1 11/16	2	2 3/8	2 3/8	2 3/8	2 3/8
MJ-8 Width of tongue, in	3125 − 002	3125 − 002	500 − 002	500 − 002	500 − 002	500 − 002	500 − 002	500 − 002
MJ-9 Depth of tongue, in	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8
MJ-10 Jaw face to body face in	3/16	3/16	3/16	3/16	5/16	5/16	5/16	5/16
MJ-11 Depth of cross slot, in	[illegible]/32	5/32	5/32	5/32	9/32	9/32	9/32	9/32
MJ-12 Tapped holes	7/16-14NC-3	1/2-13NC 3	5/8-11NC-3	5/8-11NC-3	3/4-10NC-3	3/4-10NC-3	3/4-10NC-3	3/4-10NC-3
MJ-13 Full depth of thread, in	3/4	7/8	1 1/16	1 3/16	1 1/2	1 1/2	1 1/2	1 1/2
MJ-17 Center to center of cross slots in						1 1/2	1 1/2	1 1/2
MJ-18 Number of cross slots	1	1	1	1	1	2	2	3
MJ-19 Number of tapped holes	2	2	2	3	3	4	4	5
MJ-28 Center to cross slot, jaws open in	2 7/16	3 1/16	3 13/16	4 1/2	5 5/8	5 5/8	7 1/8	7 1/8
MJ-29 Jaw extension when open in	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8

Fig 38B Dimensions for Chucks Shown in Fig 38A

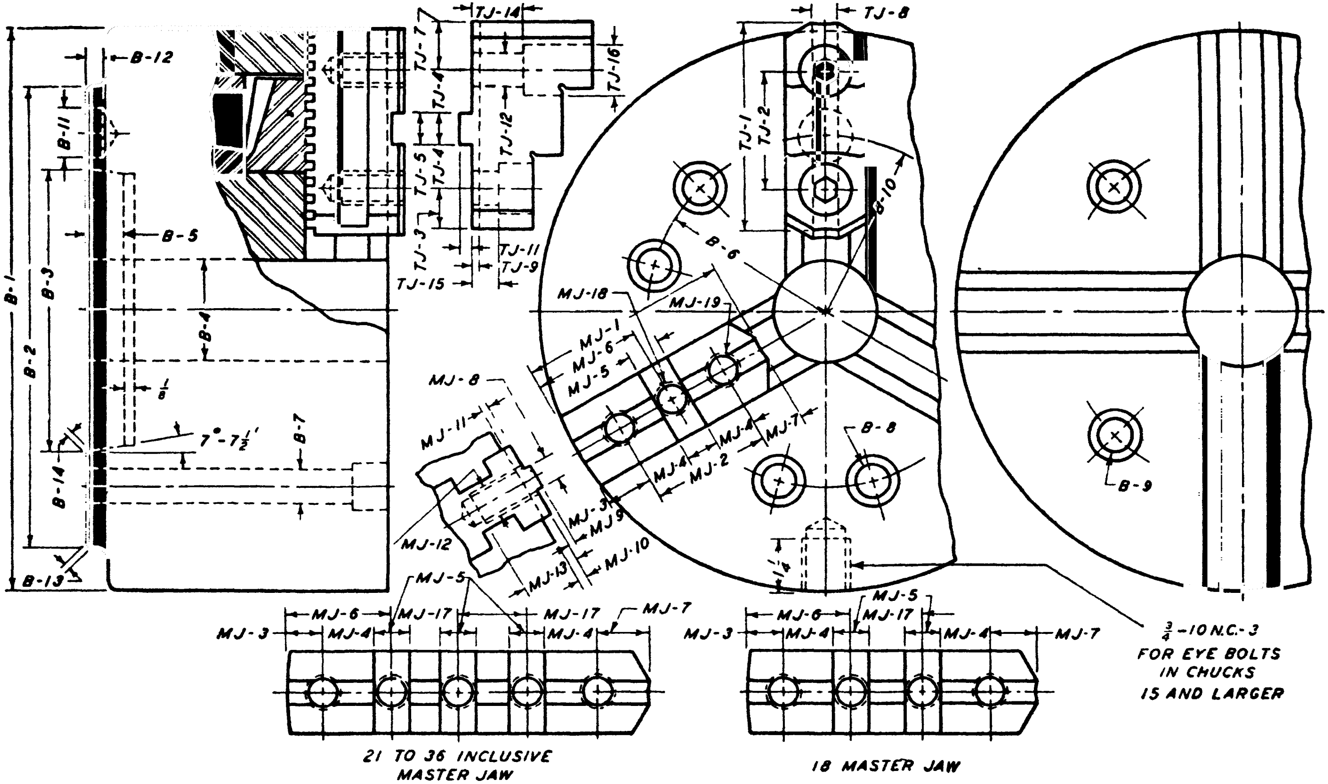


Fig. 39A. Design for Medium-Duty Hand-Operated Chucks

Medium-Duty Hand-operated Chucks

Body

Size of chuck, in.		6	8	8	10	*10	12	15	†15	‡15	24	28, 32, 36
B-1	Diam. of body, in.	6 1/2	8 1/4	8 1/4	10	10	12	15	15	15	24	28, 32, 36
B-2	Diam. of flange, in.	6 1/2	5 3/4	7 1/8	7 1/8	8 7/8	7 1/8	7 1/8	8 7/8	11 3/4	11 3/4	15 7/8
B-3	Pilot diam., in.**	4.1875	3.250	4.1875	4.1875	5.500	4.1875	4.1875	5.500	7.750	7.750	11.250
B-4	Center hole, in. (min.)	1 3/8	1 1/2	2	2 1/8	2 3/4	3	3 1/4	3 1/4	3 1/4	5	6
B-5	Depth of pilot hole, in.	9/16	1/2	9/16	9/16	5/8	9/16	9/16	5/8	11/16	11/16	3/4
B-6	Radius of bolt circle, in., scroll	2 5/8±.006	1 7/32±.006	1 5/8±.006	1 5/8±.006	2 3/16±.006	2 5/8±.006	2 5/8±.006	3 3/8±.006	3 1/4±.008	4 5/8±.008	....
B-6	Radius of bolt circle, in., ind.	2 5/8±.006	2 1/16±.006	2 5/8±.006	2 5/8±.006	3 3/8±.006	2 5/8±.006	2 5/8±.006	3 3/8±.006	4 5/8±.008	4 5/8±.008	6 1/2±.008
B-7	Drill size for bolts, in.	17/32	15/32	17/32	17/32	21/32	17/32	17/32	21/32	51/64	51/64	59/64
B-8	Bolt Nos., 3-jaw scroll	1-5-9	12-15-18	12-15-18	12-13-15 16-18-19	12-13-15 16-18-19	1-3-5 7-9-11	1-3-5 7-9-11	1-3-5 7-9-11	12-13-15 16-18-19	1-3-5 7-9-11	....
B-9	Bolt Nos., 4-jaw scroll	1-5-7-11	12-14-17-19	12-14-17-19	12-14-17-19	12-14-17-19	1-5-7-11	1-5-7-11	1-5-7-11	12-14-17-19	1-5-7-11	....
B-9	Bolt Nos., 4-jaw ind.	1-5-7-11	1-3-7-9	1-3-7-9	1-4-7-10	1-4-7-10	1-4-7-10	1-4-7-10	1-4-7-10	1-4-7-10	1-4-7-10	2-5-8-11
B-10	Radius of drive button hole, in.	2 5/8±.003	2 1/16±.003	2 5/8±.003	2 5/8±.003	3 3/8±.003	2 5/8±.003	2 5/8±.003	3 3/8±.003	4 5/8±.006	4 5/8±.006	6 1/2±.006
B-11	Diam. of drive button hole, in.	49/64+.004	41/64+.004	49/64+.004	49/64+.004	61/64+.004	49/64+.004	49/64+.004	61/64+.004	1 5/32+.004	1 5/32+.004	1 13/32+.004
B-12	Depth of drive button hole, in.	1/4	1/4	1/4	1/4	5/16	1/4	1/4	5/16	3/8	3/8	3/8
B-13	Chamfer, in.	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/8
B-14	Chamfer, in.	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/16	1/8

* A 12-inch chuck with a 12-inch body diameter is also furnished. Other dimensions are the same as shown in this column except that the center hole is 3 inches.

†An 18-inch chuck with an 18-inch body diameter is also furnished. Other dimensions are the same as shown in this column except that the center hole is 4 1/4 inches.

‡ A 21-inch chuck with a 21-inch body diameter is also furnished. Other dimensions are the same as shown in this column except that the center hole is 4 1/4 inches.

**All pilot diameters are subject to a limit of −.0005" except in the last column, where it is −.001".

Master Jaw

Size of chuck, in.		6	8	8	10	10	12	12	15	15	15	18	21	24	28, 32, 36
MJ-1	Length of jaw, in.	2 9/16	3 1/16	3 1/16	3 5/8	3 5/8	4 1/4	4 1/4	5	5	5	6 1/2	8	8	8
MJ-2	Center to center bolt hole, in.	1 1/2	1 3/4	1 3/4	2 1/8	2 1/8	1 1/4	1 1/4	1 1/2	1 1/2	1 1/2	1 1/2	1 1/2	1 1/2	1 1/2
MJ-3	Bolt center to outside edge, in.	7/16	9/16	9/16	5/8	5/8	3/4	3/4	7/8	7/8	7/8	7/8	7/8	7/8	7/8
MJ-4	Bolt center to key slot edge, in.	1/2	5/8	5/8	11/16	11/16	7/8	7/8	1 1/8	1 1/8	1 1/8	1 1/8	1 1/8	1 1/8	1 1/8
MJ-5	Width of cross slot key, in.*	.500	.500	.500	.750	.750	.750	.750	.750	.750	.750	.750	.750	.750	.750
MJ-6	Outside edge to key slot center, in.	1 3/16	1 7/16	1 7/16	1 11/16	1 11/16	2	2	2 3/8	2 3/8	2 3/8	2 3/8	2 3/8	2 3/8	2 3/8
MJ-7	Bolt center to inside edge, in.	5/8	3/4	3/4	7/8	7/8	1	1	1 1/8	1 1/8	1 1/8	1 1/8	1 1/8	1 1/8	1 1/8
MJ-8	Width of tongue, in.†	.3125	.3125	.3125	.500	.500	.500	.500	.500	.500	.500	.500	.500	.500	.500
MJ-9	Depth of tongue, in.	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8
MJ-10	Jaw face to body face, in.	3/16	3/16	3/16	3/16	3/16	3/16	3/16	5/16	5/16	5/16	5/16	5/16	5/16	5/16
MJ-11	Depth of cross slot, in.	5/32	5/32	5/32	5/32	5/32	5/32	5/32	9/32	9/32	9/32	9/32	9/32	9/32	9/32
MJ-12	Tapped holes, in.	3/8-16NC-3	3/8-16NC-3	3/8-16NC-3	1/2-13NC-3	1/2-13NC-3	1/2-13NC-3	1/2-13NC-3	5/8-11NC-3	5/8-11NC-3	5/8-11NC-3	3/4-10NC-3	3/4-10NC-3	3/4-10NC-3	3/4-10NC-3
MJ-13	Full depth of thread, in.	3/4	3/4	3/4	7/8	7/8	1	1	1 1/8	1 1/8	1 1/8	1 1/2	1 1/2	1 1/2	1 1/2
MJ-17	Center to center of cross slots, in.	......	......	......	......	......	......	......	......	......	......	1 1/2	1 1/2	1 1/2	1 1/2
MJ-18	Number of cross slots	1	1	1	1	1	1	1	1	1	1	2	3	3	3
MJ-19	Number of tapped holes	2	2	2	2	2	3	3	3	3	3	4	5	5	5

*On width of cross slot key the limit is −.001"

†On width of tongue the limit is −.002".

Fig. 39B. Dimensions for Chucks Shown in Fig. 39A

Medium-Duty Hand-operated Chucks—Cont'd.

Top Jaw

Sise of chuck, in.		6	8	10	12	15	18 to 36
TJ-1	Length of jaw, in.	2 5/8	3 1/8	3 3/4	4 5/16	5	5
TJ-2	Center to center bolt holes, in.	1 1/2	1 3/4	2 1/8	2 1/2	3	3
TJ-3	Bolt center to short bite end, in.	1/2	5/8	3/4	13/16	7/8	7/8
TJ-4	Bolt center to edge of key, in.	1/2	5/8	11/16	7/8	1 1/8	1 1/8
TJ-5	Width of cross key, in.	.499 −.001	.499 −.001	.749 −.001	.749 −.001	.749 −.001	.749 −.001
TJ-7	Bolt center to long bite end, in.	5/8	3/4	7/8	1	1 1/8	1 1/8
TJ-8	Width of tongue slot, in.	.3155 −.002	.3155 −.002	.503 −.002	.503 −.002	.503 −.002	.503 −.002
TJ-9	Depth of tongue slot, in.	5/32	5/32	5/32	5/32	5/32	5/32
TJ-11	Depth of cross key, in.	1/8	1/8	1/8	1/8	1/4	1/4
TJ-12	Drill sise for bolts, in.	25/64	25/64	33/64	33/64	41/64	49/64
TJ-14	Depth of C'bore long bite end, in.	17/32	11/16	25/32	27/32	27/32	1 27/32
TJ-15	Depth of C'bore short bite end, in.	7/32	11/32	9/32	11/32	11/32	15/32
TJ-16	C'bore for bolt head, in.	37/64	37/64	49/64	49/64	57/64	1 1/64

Fig. 39C. Dimensions for Chucks Shown in Fig. 39A

manufacturers) a two-jaw chuck as shown by Fig. 34 is frequently used. You will note from this illustration that the four-arm spider is gripped in a wrenchless chuck by means of special jaws which are designed so that they will index the work piece. The first arm of the spider is rough turned, faced, and drilled at one position in the turret and the front cross slide of this special machine. The arm that has been roughed is then finished with the second position of the turret and the rear cross slide of the machine. As the turret of the machine returns for indexing, the four-arm spider is automatically indexed in the chuck and the subsequent operations take place on each arm until the differential spider is completed.

Fig. 35 illustrates a top view of this machine with tools in place, and the rough and finished forgings of the four-arm spider are shown on the bed of the machine.

In drilling small pieces of irregular shape that are difficult to hold in ordinary jigs, wrenchless chucks equipped with special step jaws are used in conjunction with drill presses. Fig. 36 illustrates three 2-jaw wrenchless chucks with special step jaws for machining pipe fittings and brass water faucets. This is a very good illustration of the variety of work that can be handled in chucks, provided the jaws are of correct design. These chucks, in combination with specially designed step jaws, are capable of increasing production considerably, which will reduce the cost of tooling.

On high-production jobs where there are large quantities of small parts, chucks can be designed with special jaws so as to accommodate a number of pieces. Fig. 37 illustrates a design of chuck

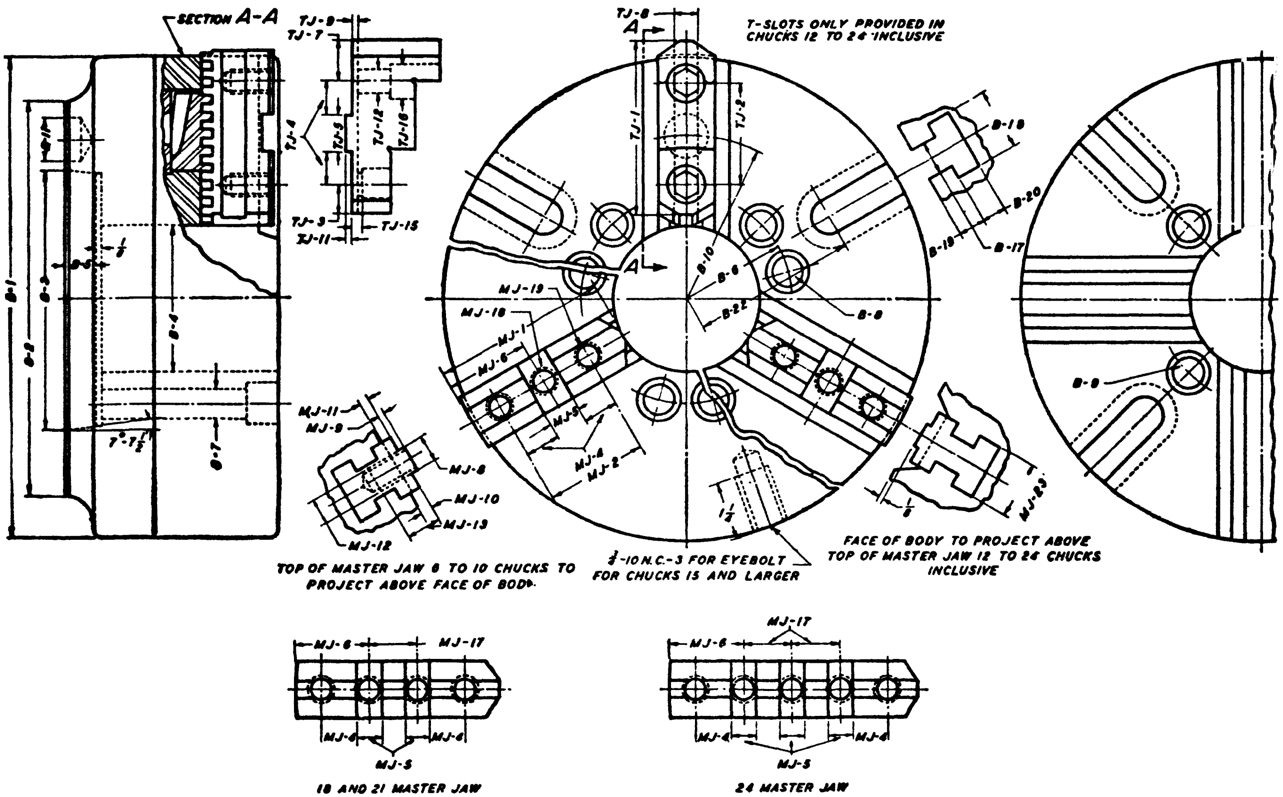


Fig. 40A. Design for Hand-Operated Tongue-and-Groove Heavy-Duty Chucks for Use on Heavy-Duty Turret and Automatic Lathes

Hand-operated Tongue-and-Groove Heavy-Duty Chucks for Use on Heavy-Duty Turret and Automatic Lathes

In this Table, B = Body; MJ = Master Jaw; TJ = Top Jaw

Size of chuck, in.		6	8	10	12	15	18	21	24
B-1	Diam. of body, in.	6 1/2	8 1/4	10	12	15	18	21	24
B-2	Diam. of flange, in.	5 3/4	7 1/8	8 7/8	8 7/8	11 3/4	11 3/4	15 7/8	15 7/8
B-3	Pilot diam., in.	3.250−.0005	4.1875−.0005	5.500−.0005	5.500−.0005	7.750−.0005	7.750−.0005	11.250−.001	11.250−.001
B-4	Center hole (min.), in.	1 3/8	2	2 3/4	3	5	5	8	8
B-5	Depth of pilot hole, in.	1/2	9/16	5/8	5/8	11/16	11/16	3/4	3/4
B-6	Radius of bolt circle, scroll, in.	1 7/32 ± .006	1 5/8 ± .006	2 3/16 ± .006	2 3/16 ± .006	3 1/4 ± .008	3 1/4 ± .008	4 7/8 ± .008	6 1/2 ± .008
B-7	Drill size for bolts, in.	15/32	17/32	21/32	21/32	51/64	51/64	59/64	59/64
B-8	Bolt No. 3-jaw, scroll	12-15-18	12-13-15-16 18-19	12-13-15-16 18-19	12-13-15-16 18-19	12-13-15-16 18-19	12-13-15-16 18-19	13-14-17-18 21-22	1-3-5-7 9-11
B-9	Bolt No. 4-jaw, scroll	12-14-17-19	12-14-17-19	12-14-17-19	12-14-17-19	12-14-17-19	12-14-17-19	13-14-16-17 19-20-22-23	1-2-4-5-7 8-10-11
B-10	Radius of drive button hole, in.	2 1/16 ± .003	2 5/8 ± .003	3 3/8 ± .003	3 3/8 ± .003	4 5/8 ± .006	4 5/8 ± .006	6 1/2 ± .006	6 1/2 ± .006
B-11	Diam of drive button hole, in.	41/64 + .004	49/64 + .004	61/64 + .004	61/64 + .004	1 5/32 + .004	1 5/32 + .004	1 13/32 + .004	1 13/32 + .004
B-17	Width of throat, in.	...	...	...	11/16 ± 1/64	13/16 ± 1/64	13/16 ± 1/64	13/16 ± 1/64	13/16 ± 1/64
B-18	Width of key slot, in.	...	...	...	1 1/4 ± 1/16	1 15/32 ± 1/32	1 15/32 ± 1/32	1 15/32 ± 1/32	1 15/32 ± 1/32
B-19	Depth of throat, in.	...	...	...	7/16 to 7/8	9/16 to 1 1/16	9/16 to 1 1/16	9/16 to 1 1/16	9/16 to 1 1/16
B-20	Depth of key slot, in.	...	...	...	31/64 − 1/32	5/8 − 1/32	5/8 − 1/32	5/8 − 1/32	5/8 − 1/32
B-22	Radius to center of T-slot cutter, in.	...	...	...	3 3/8	4 5/8	4 5/8	5 5/8	5 5/8
MJ-1	Length of jaw, in.	2 9/16	3 1/16	3 5/8	4 1/4	5	6 1/2	6 1/2	8
MJ-2	Center to center bolt holes, in.	1 1/2	1 3/4	2 1/8	1 1/4	1 1/2	1 1/2	1 1/2	1 1/2
MJ-4	Bolt center to key slot edge, in.	1/2	5/8	11/16	7/8	1 1/8	1 1/8	1 1/8	1 1/8
MJ-5	Width of cross slot key, in.	.500−.001	.500−.001	.750−.001	.750−.001	.750−.001	.750−.001	.750−.001	.750−.001
MJ-6	Outside edge to key slot center, in.	1 3/16	1 7/16	1 11/16	2	2 3/8	2 3/8	2 3/8	2 3/8
MJ-8	Width of tongue, in.	.3125−.002	.3125−.002	.500−.002	.500−.002	.500−.002	.500−.002	.500−.002	.500−.002
MJ-9	Depth of tongue, in.	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8
MJ-10	Jaw face to body face, in.	3/16	3/16	3/16	...	...	...	...	...
MJ-11	Depth of cross slot, in.	5/32	5/32	5/32	5/32	9/32	9/32	9/32	9/32
MJ-12	Tapped holes, in.	7/16-14NC-3	1/2-13NC-3	5/8-11NC-3	5/8-11NC-3	3/4-10NC-3	3/4-10NC-3	3/4-10NC-3	3/4-10NC-3
MJ-13	Full depth of thread, in.	3/4	7/8	1 1/16	1 3/16	1 1/2	1 1/2	1 1/2	1 1/2
MJ-17	Center to center of cross slots, in.	...	...	...	...	...	1 1/2	1 1/2	1 1/2
MJ-18	Number of cross slots	1	1	1	1	1	2	2	3
MJ-19	Number of tapped holes	2	2	2	3	3	4	4	5
MJ-23	Width of jaw minimum, in.	1 1/8	1 1/8	1 3/4	1 3/4	2	2	2	2
TJ-1	Length of jaw, in.	2 5/8	3 1/8	3 3/4	4 5/16	5	5	5	5
TJ-2	Center to center bolt holes, in.	1 1/2	1 3/4	2 1/8	2 1/2	3	3	3	3
TJ-3	Bolt center to short bite end, in.	1/2	5/8	3/4	13/16	7/8	7/8	7/8	7/8
TJ-4	Bolt center to edge of key, in.	1/2	5/8	11/16	7/8	1 1/8	1 1/8	1 1/8	1 1/8
TJ-5	Width of cross key, in.	.499−.001	.499−.001	.749−.001	.749−.001	.749−.001	.749−.001	.749−.001	.749−.001
TJ-7	Bolt center to long bite end, in.	5/8	3/4	7/8	1	1 1/8	1 1/8	1 1/8	1 1/8
TJ-8	Width of tongue slot, in.	.3155−.002	.3155−.002	503−.002	.503−.002	.503−.002	.503−.002	.503−.002	.503−.002
TJ-9	Depth of tongue slot, in.	5/32	5/32	5/32	5/32	5/32	5/32	5/32	5/32
TJ-11	Depth of cross key, in.	1/8	1/8	1/8	1/8	1/4	1/4	1/4	1/4
TJ-12	Drill size for bolts, in.	19/64	33/64	41/64	41/64	49/64	49/64	49/64	49/64
TJ-15	Depth of C'bore short bite end, in.	9/32	11/32	11/32	13/32	15/32	15/32	15/32	15/32
TJ-16	C'bore for bolt head, in.	41/64	49/64	57/64	57/64	1 1/64	1 1/64	1 1/64	1 1/64

Fig. 40B. Dimensions for Chucks Shown in Fig. 40A

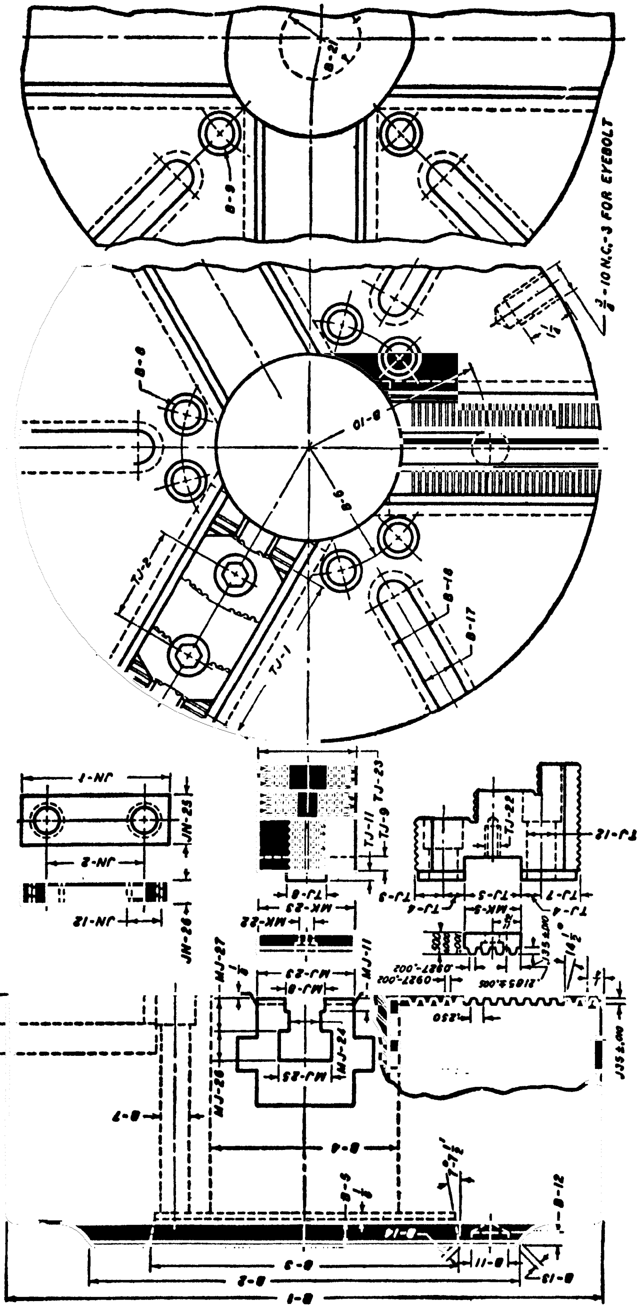


Fig. 41A. Design for Serrated Jaw Type Heavy-Duty Chucks, Power and Hand Operated

Serrated Jaw Type Heavy-Duty Chucks, Power and Hand-operated

Body

	Size of chuck, in.	15	18	21	24	28	32	36
B-1	Diam of body, in	15	18	21	24	28	32	36
B-2	Diam of flange, in	11 3/4	11 3/4	15 7/8	15 7/8	21 1/2	21 1/2	21 1/2
B-3	Pilot diam, in	7 750 − 0005	7 750 − 0005	11.250 − 001	11 250 − 001	16 250 − 001	16.250 − 001	16 250 − 001
B-4	Center hole, in	5	5	8	8	11	12 3/4	12 3/4
B-5	Depth of pilot hole, in	11/16	11/16	3/4	3/4	13/16	13/16	13/16
B-6	Radius of bolt circle, scroll chucks, in	3 1/4 ± 008	3 1/4 ± 008	4 7/8 ± 008	6 1/2 ± 008	7 1/4 ± 008	9 1/8 ± 008	9 1/8 ± 008
B-6	Radius of bolt circle, for power and ind chucks, in	4 5/8 ± 008	4 5/8 ± 008	6 1/2 ± 008	6 1/2 ± 008	9 1/8 ± 008	9 1/8 ± 008	9 1/8 ± 008
B-7	Drill size for bolts, in	51/64	51/64	59/64	59/64	1 3/64	1 3/64	1 3/64
B-8	Bolt No scroll chucks, 3-jaw	12-13-15-16 18-19	12-13-15-16 18-19	13-14-17-18 21-22	2-3-6-7 10-11	13-14-17-18 21-22	2-3-6-7 10-11	2-3-6-7 10-11
B-8	Bolt No power chucks 3-jaw	2-3-6-7 10-11	2 3-6-7 10-11	2-3-6-7 10-11	2-3-6-7 10-11	2-3-6-7 10-11	2-3-6-7 10-11	2-3-6-7 10-11
B-9	Bolt No independent chucks	1-2-4-5-7 8-10-11	1 2-4-5-7 8-10-11	1 2-4-5-7 8-10-11	1-2-4-5-7 8-10-11	1-2-4-5-7 8-10-11	1-2-4-5-7 8-10-11	1-2-4-5-7 8-10-11
B-9	Bolt No scroll chucks, 4-jaw	12-14-17-19	12-14-17-19	13-14-16-17 19-20-22-23	1 2-4-5-7 8-10-11	13-14-16-17 19-20-22-23	1-2-4-5-7 8-10-11	1-2-4-5-7 8-10-11
B-10	Radius of drive button hole, in	4 5/8 ± 006	4 5/8 ± 006	6 1/2 ± 006	6 1/2 ± 006	9 1/8 ± 006	9 1/8 ± 006	9 1/8 ± 006
B-11	Diam of drive button hole, in	1 5/32 + 004	1 5/32 + 004	1 13/32 + 004	1 13/32 + 004	1 21/32 + 004	1 21/32 + 004	1 21/32 ± 004
B-12	Depth of drive button hole, in	3/8	3/8	3/8	3/8	3/8	3/8	3/8
B-13	Chamfer, in	1/16	1/16	1/8	1/8	1/8	1/8	1/8
B-14	Chamfer, in	1/16	1/16	1/8	1/8	1/8	1/8	1/8
B-17	Width of throat, in	13/16 ± 1/64	13/16 ± 1/64	13/16 ± 1/64	13/16 ± 1/64	13/16 ± 1/64	13/16 ± 1/64	13/16 ± 1/64
B-18	Width of key slot, in	1 15/32 − 3/32	1 15/32 − 3/32	1 15/32 − 3/32	1 15/32 − 3/32	1 15/32 − 3/32	1 15/32 − 3/32	1 15/32 − 3/32
B-19	Depth of throat, in	13/16 ± 1/16	13/16 ± 1/16	13/16 ± 1/16	13/16 ± 1/16	13/16 ± 1/16	13/16 ± 1/16	13/16 ± 1/16
B-20	Depth of key slot, in	5/8 − 1/32	5/8 − 1/32	5/8 − 1/32	5/8 − 1/32	5/8 − 1/32	5/8 − 1/32	5/8 − 1/32
B-21	Pilot bar diam for power chucks, in	2	2 1/2	3	3			

Master Jaw

	Size of chuck, in	15	18	21	24	28	32	36
MJ-8	Width of tongue slot, in	1 000 + 002	1 000 + 002	1 250 + 002	1 250 + 002	1 250 + 002	1.250 + 002	1.250 + 002
MJ-11	Depth of tongue slot, in	5/16 ± 1/32	5/16 ± 1/32	5/16 ± 1/32	5/16 ± 1/32	5/16 ± 1/32	5/16 ± 1/32	5/16 ± 1/32
MJ-23	Width of jaw, in	2 7/16	2 7/16	2 15/16	2 15/16	2 15/16	2 15/16	2 15/16
MJ-24	Width of throat, in	13/16 ± 1/64	13/16 ± 1/64	15/16 ± 1/64	15/16 ± 1/64	15/16 ± 1/64	15/16 ± 1/64	15/16 ± 1/64
MJ-25	Width of key slot, in	1 5/16 ± 1/32	1 5/16 ± 1/32	1 1/2 ± 1/32	1 1/2 ± 1/32	1 1/2 ± 1/32	1 1/2 ± 1/32	1 1/2 ± 1/32
MJ-26	Depth of key slot, in	3/4 ± 1/32	3/4 ± 1/32	7/8 ± 1/32	7/8 ± 1/32	7/8 ± 1/32	7/8 ± 1/32	7/8 ± 1/32
MJ-27	Depth of throat, in	3/4 ± 1/32	3/4 ± 1/32	1 ± 1/32	1 ± 1/32	1 ± 1/32	1 ± 1/32	1 ± 1/32

Fig 41B Dimensions for Chucks Illustrated in Fig 41A

Serrated Jaw Heavy-Duty Chucks, Power and Hand-operated—Cont'd.

Master Key

Size of chuck, in.	15	18	21	24
MK-5 Length of key, in.	1.4375 −.001	1.4375 −.001	1.4375 −.001	1.4375 −.001
MK-22 Size of screw, in.	3/8x3/4 Fil. Hd.	3/8x3/4 Fil. Hd.	3/8x3/4 Fil. Hd.	3/8x3/4 Fil. Hd.
MK-23 Width of key, in.	2 3/8	2 3/8	2 7/8	2 7/8
Size of chuck, in.	**28**	**32**	**36**	....
MK-5 Length of key, in.	1.4375 −.001	1.4375 −.001	1.4375 −.001	....
MK-22 Size of screw, in.	3/8x3/4 Fil. Hd.	3/8x3/4 Fil. Hd.	3/8x3/4 Fil. Hd.	....
MK-23 Width of key, in.	2 7/8	2 7/8	2 7/8	....

Reversible Top Jaw

Size of chuck, in.	15	18	21	24
TJ-1 Length of jaw, in.	4 1/4	4 1/4	5 3/4	5 3/4
TJ-2 Center to center bolt holes, in.	2 1/2	2 1/2	3	3
TJ-3 Bolt center to short bite end, in.	3/4	3/4	1 3/8	1 3/8
TJ-4 Bolt center to edge of key slot, in.	17/32	17/32	25/32	25/32
TJ-5 Width of key slot, in.	1.4375 +.001	1.4375 +.001	1.4375 +.001	1.4375 +.001
TJ-7 Bolt center to long bite end, in.	1	1	1 3/8	1 3/8
TJ-8 Width of tongue, in.	.998 −.003	.998 −.003	1.248 −.003	1.248 −.003
TJ-9 Depth of key slot, in.	.375 +.001	.375 +.001	.375 +.001	.375 +.001
TJ-11 Depth of tongue, in.	1/4 ± 1/64	1/4 ± 1/64	1/4 ± 1/64	1/4 ± 1/64
TJ-12 Drill size for bolts, in.	25/32	25/32	29/32	29/32
TJ-22 Tapped holes, in.	3/8-16NC-2	3/8-16NC-2	3/8-16NC-2	3/8-16NC-2
TJ-23 Width of jaw, in.	2 3/8	2 3/8	2 7/8	2 7/8
Size of chuck, in.	**28**	**32**	**36**	
TJ-1 Length of saw, in.	5 3/4	5 3/4	5 3/4	....
TJ-2 Center to center bolt holes, in.	3	3	3	....
TJ-3 Bolt center to short bite end, in.	1 3/8	1 3/8	1 3/8	....
TJ-4 Bolt center to edge of key slot, in.	25/32	25/32	25/32	....
TJ-5 Width of key slot, in.	1.4375 +.001	1.4375 +.001	1.4375 +.001	....
TJ-7 Bolt center to long bite end, in.	1 3/8	1 3/8	1 3/8	....
TJ-8 Width of tongue, in.	1.248 −.003	1.248 −.003	1.248 −.003	....
TJ-9 Depth of key slot, in.	.375 +.001	.375 +.001	.375 +.001	....
TJ-11 Depth of tongue, in.	1/4 ± 1/64	1/4 ± 1/64	1/4 ± 1/64	....
TJ-12 Drill size for bolts, in.	29/32	29/32	29/32	....
TJ-22 Tapped holes, in.	3/8-16NC-2	3/8-16NC-2	3/8-16NC-2	....
TJ-23 Width of jaw, in.	2 7/8	2 7/8	2 7/8	....

Jaw Nut

Size of chuck, in.	15	18	21	24
JN-1 Length of nut, in.	3 3/4	3 3/4	4 7/16	4 7/16
JN-2 Center to center tapped holes, in.	2 1/2	2 1/2	3	3
JN-12 Tapped holes, in.	3/4-10NC-2	3/4-10NC-2	7/8-9NC-2	7/8-9NC-2
JN-25 Width of nut, in.	1 1/4 ± 1/64	1 1/4 ± 1/64	1 7/16 ± 1/64	1 7/16 ± 1/64
JN-26 Depth of nut, in.	11/16 ± 1/64	11/16 ± 1/64	13/16 ± 1/64	13/16 ± 1/64
Size of chuck, in.	**28**	**32**	**36**	
JN-1 Length of nut, in.	4 7/16	4 7/16	4 7/16	....
JN-2 Center to center tapped holes, in.	3	3	3	....
JN-12 Tapped holes, in.	7/8-9NC-2	7/8-9NC-2	7/8-9NC-2	....
JN-25 Width of nut, in.	1 7/16 ± 1/64	1 7/16 ± 1/64	1 7/16 ± 1/64	....
JN-26 Depth of nut, in.	13/16 ± 1/64	13/16 ± 1/64	13/16 ± 1/64	....

Fig. 41C. Dimensions for Chucks Illustrated in Fig. 41A

for holding three pieces at one time. These jaws are capable of being individually adjusted, and the chuck itself is mounted on an index table so that the pieces will be in direct line with the spindle of a drill press. Note that these chuck jaws are serrated so as to prevent slipping of the work in the chuck jaw.

To design jaws for various types of chucks, it is necessary that

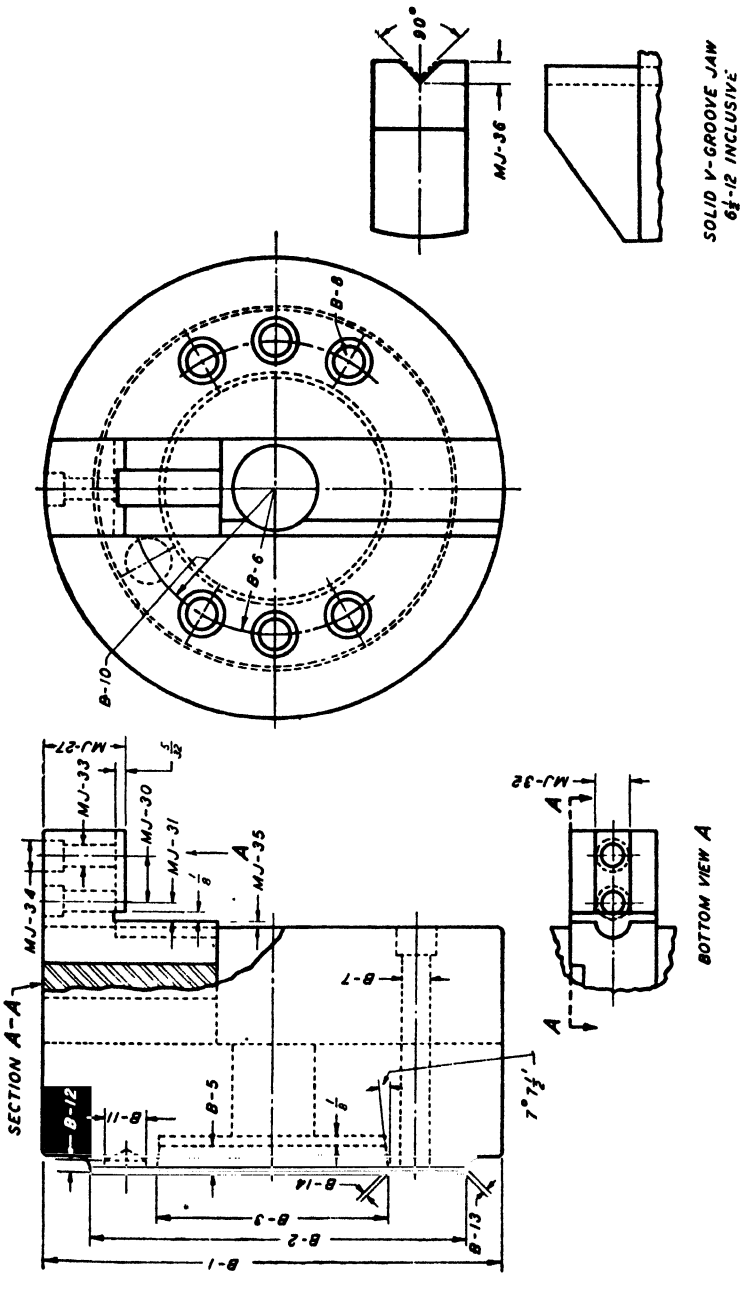


Fig. 42A. Design of Medium-Duty Two-Jaw Wrench-Operated Chucks for Turret and Automatic Lathes

Medium-Duty Two-Jaw Wrench-operated Chucks for Turret and Automatic Lathes

Body

Size of chuck, in.	6	8	*10	†15
B-1 Diam. of body, in.	6 1/2	8 1/4	10	15
B-2 Diam. of flange, in.	6 1/2	7 1/8	7 1/8	8 7/8
B-3 Pilot diam. in.	4.1875 −.0005	4.1875 −.0005	4.1875 −.0005	5.500 −.0005
B-5 Depth of pilot hole, in.	9/16	9/16	9/16	5/8
B-6 Radius of bolt circle, in.	2 5/8 ±.006	2 5/8 ±.006	2 5/8 ±.006	3 3/8 ±.006
B-7 Drill size for bolts, in.	17/32	17/32	17/32	21/32
B-8 Bolt numbers, in.	4-5-10-11	4-5-10-11	4-5-10-11	3-4-5 9-10-11
B-10 Radius of drive button hole, in.	2 5/8 ±.003	2 5/8 ±.003	2 5/8 ±.003	3 3/8 ±.003
B-11 Diam. of drive button hole, in.	49/64 +.004	49/64 +.004	49/64 +.004	61/64 +.004
B-12 Depth of drive button hole, in.	1/4	1/4	1/4	5/16
B-13 Chamfer, in.	1/16	1/16	1/16	1/16
B-14 Chamfer, in.	1/16	1/16	1/16	1/16

*A 12-inch chuck with a 12-inch body diameter is also made. Other dimensions are the same as shown in this column.

†An 18-inch chuck with an 18-inch body diameter is also made. Other dimensions are as shown in this column.

Master Jaw, Slip-Jaw Type

Size of chuck, in.	6	8	10	12	15	18
MJ-27 Length of horn, in.	1 1/2	1 1/2	1 1/2	2	2 1/2	3
MJ-30 Center to center bolt holes, in.	7/8	7/8	7/8	2	2	2
MJ-31 Bolt center to face of jaw, in.	3/8	3/8	3/8	7/16	7/16	7/16
MJ-32 Width of tongue slot, in.	.625 −.001	.625 −.001	.625 −.001	.750 −.001	.750 −.001	.750 −.001
MJ-33 Drill size for bolts, in.	25/64	25/64	25/64	33/64	33/64	33/64
MJ-34 C'bore for bolt head, in.	37/64	37/64	37/64	49/64	49/64	49/64
MJ-35 Face of jaw to face of chuck, in.	1/16	1/16	1/16	1/8	1/8	1/8
MJ-36 Depth of V-groove, in.	5/16	3/8	3/8	7/16	......	....

Fig. 42B. Dimensions for Chucks Shown in Fig. 42A

the tool designer have some standard to guide him, as all of these chucks are made in accordance with the standards of the American Standards Association. Fig. 38A is the design of tongue-and-groove type, power-operated chucks for turret lathes and automatic lathes; Fig. 38B is a table giving dimensions. The tool designer can refer to these figures and readily design jaws suitable for the work piece.

Fig. 39A is the design for medium-duty hand-operated chucks. The tables presented as Figs. 39B and 39C contain all the necessary information to enable the tool designer to adapt the size of chuck and design jaws suited to the job required.

The drawing on Fig. 40A and the table on Fig. 40B contain all necessary data and information for hand-operated tongue-and-groove type heavy-duty chucks.

Fig. 41A is the design, and Figs. 41B and 41C are the tables, showing power and hand-operated heavy-duty chucks with serrated jaws. The table contains all the necessary information for the tool designer so that he can design special jaws that can readily be adapted to chucks of this type.

Figs. 42A and 42B are the design and table of dimensions for medium-duty two-jaw wrench-operated chucks. This type of chuck is extensively used in metalworking plants on turret lathes and automatic lathes.

TURRET LATHES

Designing tools for use in turret lathes is something of a specialty. This type of machine tool is used for an infinite variety of work in the average metalworking plant that is equipped with these machines. There are many different types of turret lathes, but they can be classified under two main groups: the horizontal and the vertical. Horizontal turret lathes are the most widely used and can be subdivided into two groups; namely, chucking machines and bar machines. Chucking machines grip the work in chucks, collets, or specially designed fixtures, or on face plates. The bar machines are somewhat similar and are basically the same as chucking machines except that the bar machines have large bores in the spindle to accommodate a long bar of material entirely through the headstock of the machine. The tools for the chucking machines and the bar machines are somewhat similar, although in the bar machine it is simpler to design tools so as to obtain considerable rigidity. It is apparent to the tool designer that in the chucking machines a somewhat different problem exists, as there is often considerable overhang of the work due to the nature of the design of the work piece, such as forgings, castings, etc.

It is necessary for the tool designer, in designing tools for either bar or chucking machines, to keep in mind the fact that these tools must be designed to be as strong as possible in order to obtain the necessary rigidity. It is essential that the tools be as simple as they can be made, to avoid difficulty in resetting them after grinding. The tools for turret lathes of all types are similar to those used on a wide variety of other types of machine tools. The same cutting principles apply to turret lathes as to engine lathes, milling machines, boring mills or any other type of machine tool.

Fig. 43 illustrates a turret lathe completely tooled. It will be noted from this illustration that tools are mounted on the front and rear cross slides. All six holes in the turret have been equipped with various types of tools. A chuck with jaws is mounted on the headstock end of this turret lathe, and it will be noted from the design of the chuck that these jaws are arranged for gripping the work on the outside diameter.

The turret lathe can produce repetitious work very rapidly. For example, on a casting the cross slide can be used to feed across the face of the work while the drill in the turret is drilling the center hole. The various other tools mounted in the turret may be used in rapid succession to complete the piece at one setting. This is an outstanding advantage over the engine lathe where, for machining the same type of casting, usually only one tool can work at a time. The casting could be chucked in the engine lathe and a single-point tool bit used to face off the front end of the casting. If it were necessary to drill a hole through the center of this casting, the tailstock would be used to hold a drill chuck that would fit the quill of a tailstock. This tailstock containing the drill and chuck would be moved up close to the work, and the tailstock locked in position on the bed of the lathe; then the drill would be fed forward by means of a screw in the tailstock. In some instances in engine lathes it would be necessary to reset the piece one or more times, in addition to changing tools, to complete it. It therefore can readily be seen that a turret lathe is the machine to use for certain types

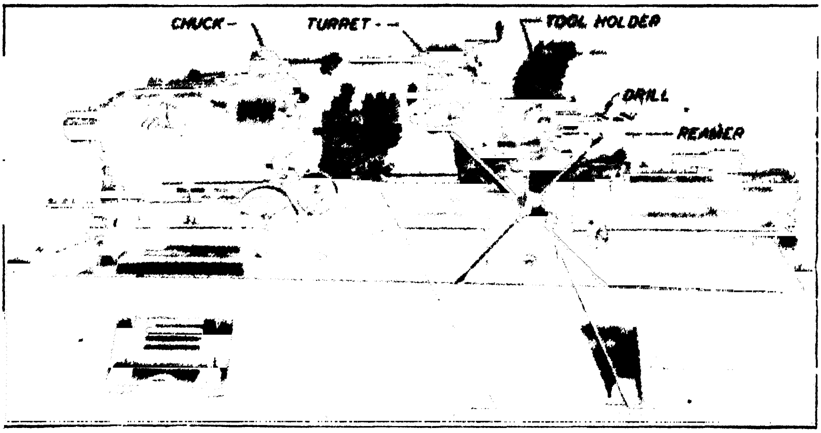


Fig 43 Turret Lathe Completely Tooled
Courtesy of Jones & Lamson Co , Springfield, Vt

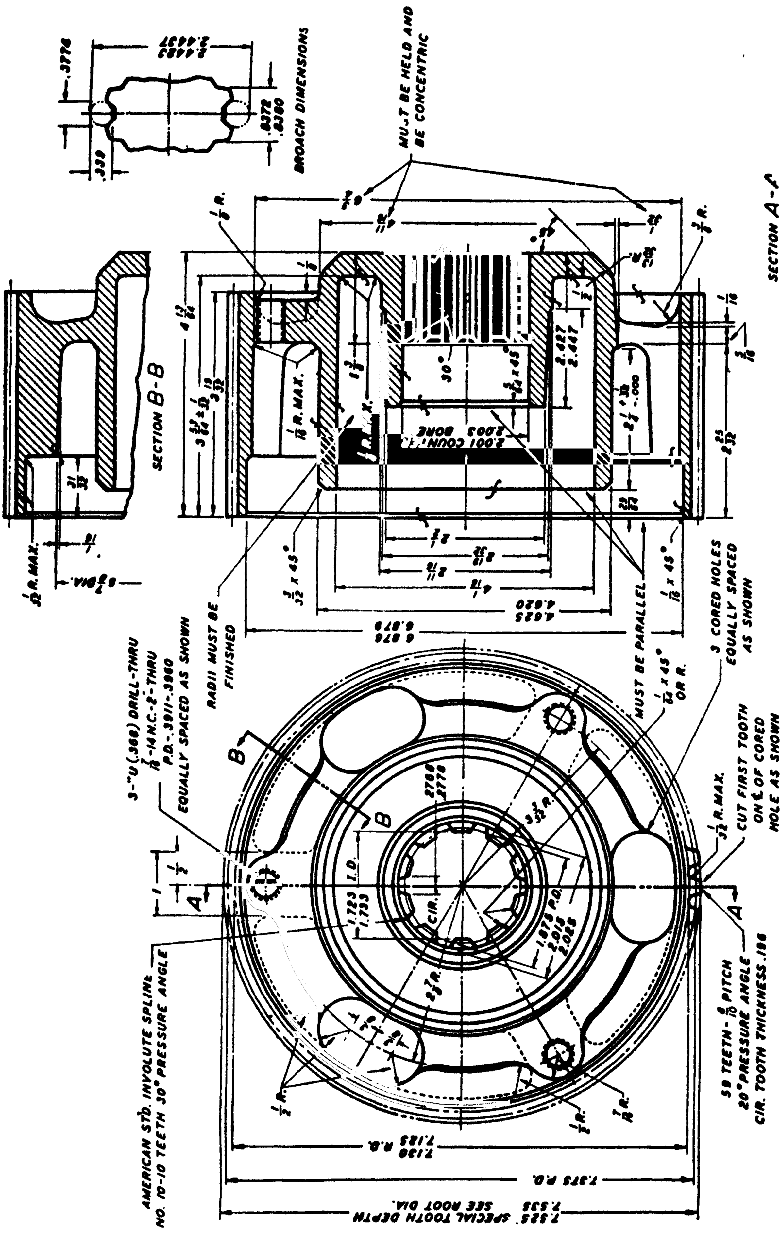


Fig. 44. Steering Clutch Hub

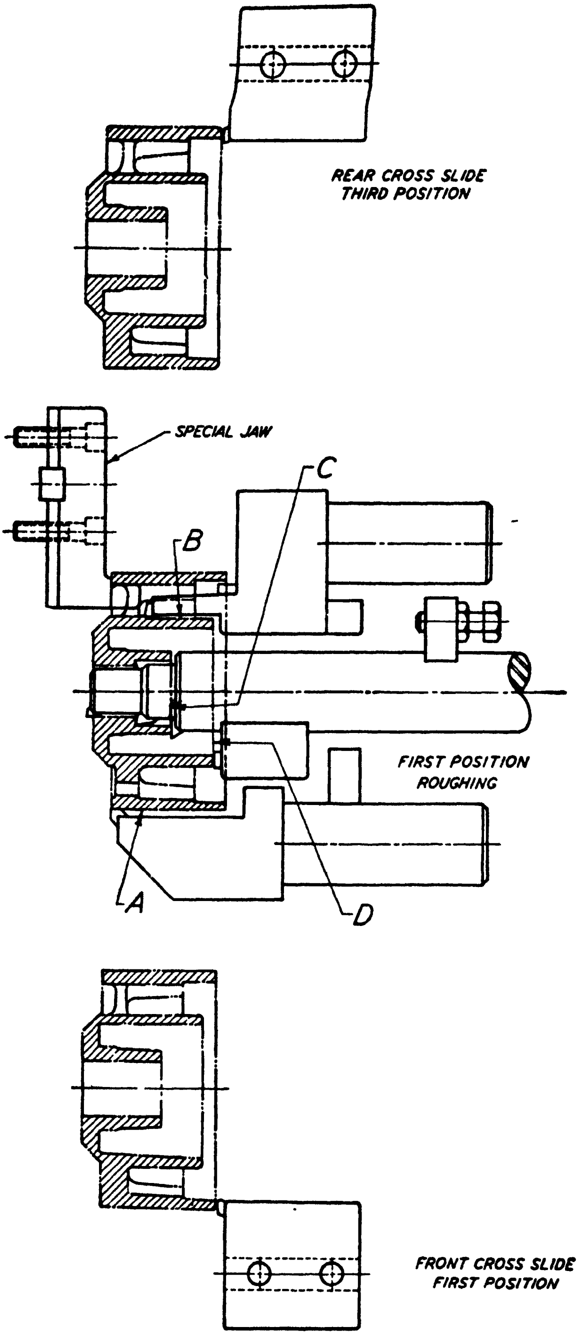


Fig. 45A. This Figure and Fig. 45B Show the Tool Layout for Five Positions in a Turret

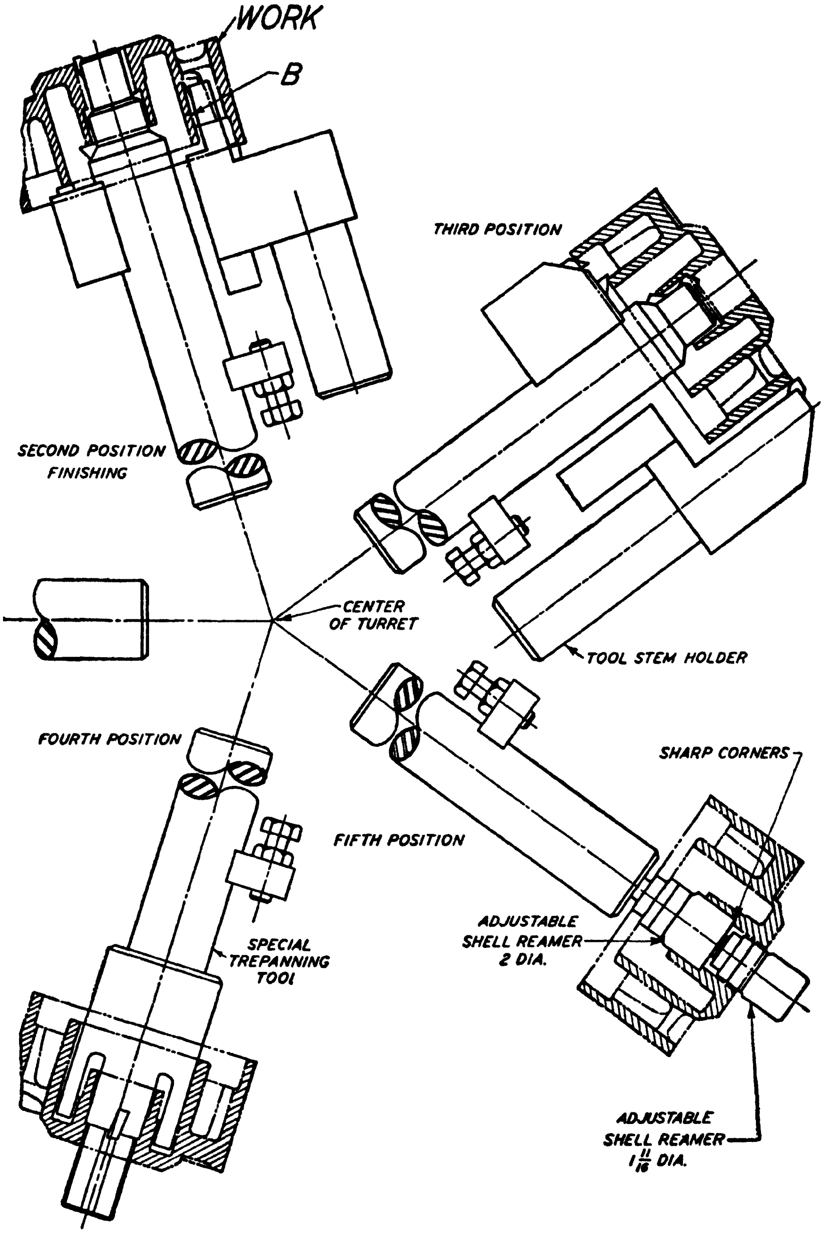


Fig. 45B. This Complete Setup Is for Machining the Piece Part Shown in Fig. 44

of production work because practically all the necessary operations can be performed in one setup.

In designing tools for turret lathes, the design of the piece part is carefully analyzed to see whether it would be more suitable for production on a turret lathe or on some other type of machine. After it has been decided that the job is to be produced in a turret lathe, the piece part is again carefully checked to see what operations will be performed. When it is determined that certain operations on this work piece are going to be tooled, the job is routed

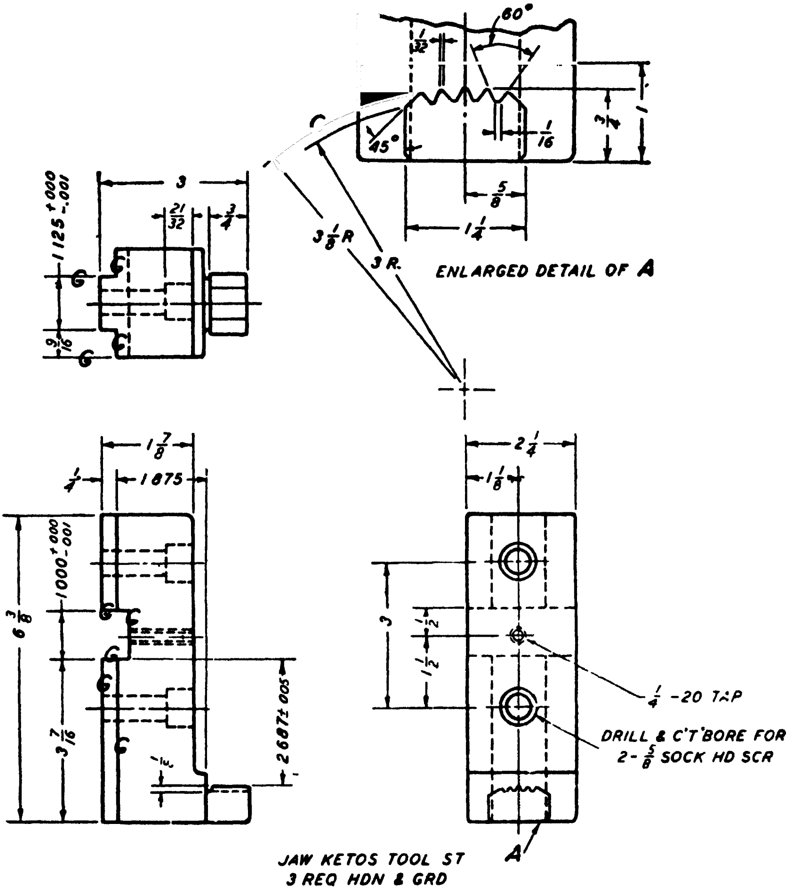
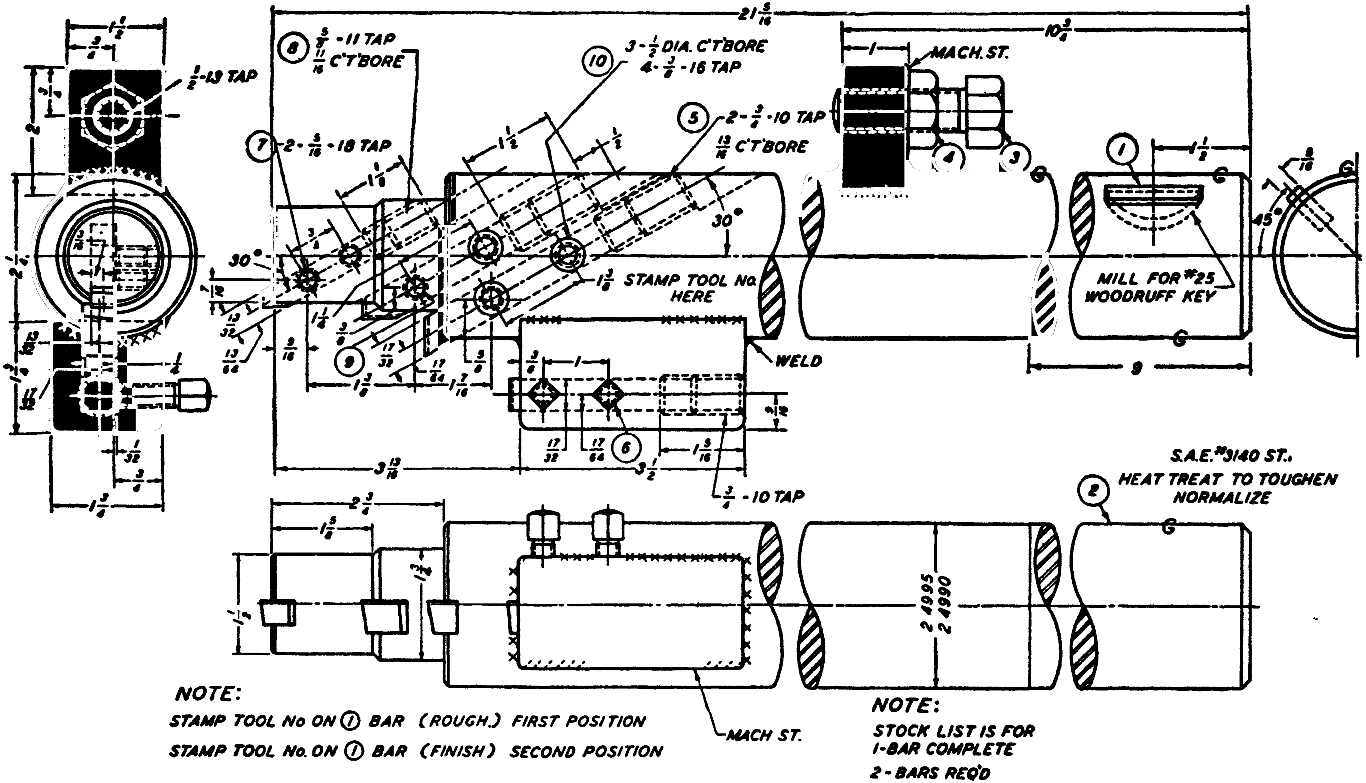


Fig. 45C. Details of the Design Shown in Figs. 45A and 45B



NOTE:
STAMP TOOL No ON ① BAR (ROUGH.) FIRST POSITION
STAMP TOOL No. ON ① BAR (FINISH) SECOND POSITION

NOTE:
STOCK LIST IS FOR
1-BAR COMPLETE
2 - BARS REQ'D

Fig. 46A. Design of Boring Bar Used in First and Second Positions of the Turret Setup Shown in Figs. 45A and 45B

10	SOCKET SET SCREW	STANDARD	3	$\frac{3}{8}$-16 x 1
9	SOCKET SET SCREW	STANDARD	1	$\frac{3}{8}$-16 x $\frac{3}{4}$
8	SOCKET SET SCREW	STANDARD	1	$\frac{5}{8}$-11 x $\frac{3}{4}$
7	SOCKET SET SCREW	STANDARD	2	$\frac{5}{16}$-18 x $\frac{1}{2}$
6	SQUARE HEAD SET SCREW	STANDARD	2	$\frac{3}{8}$-16 x 1
5	SOCKET SET SCREW	STANDARD	3	$\frac{3}{4}$-10 x 1
4	HEXAGON NUT	STANDARD	1	$\frac{1}{2}$-13
3	HEXAGON HEAD SCREW	STANDARD	1	$\frac{1}{2}$-13 x 2
2	BORING BAR	MACH. ST.	1	WELDED CONST.
1	WOODRUFF KEY	STANDARD	1	#25
NO.	NAME	MATERIAL	REQ.	SIZE

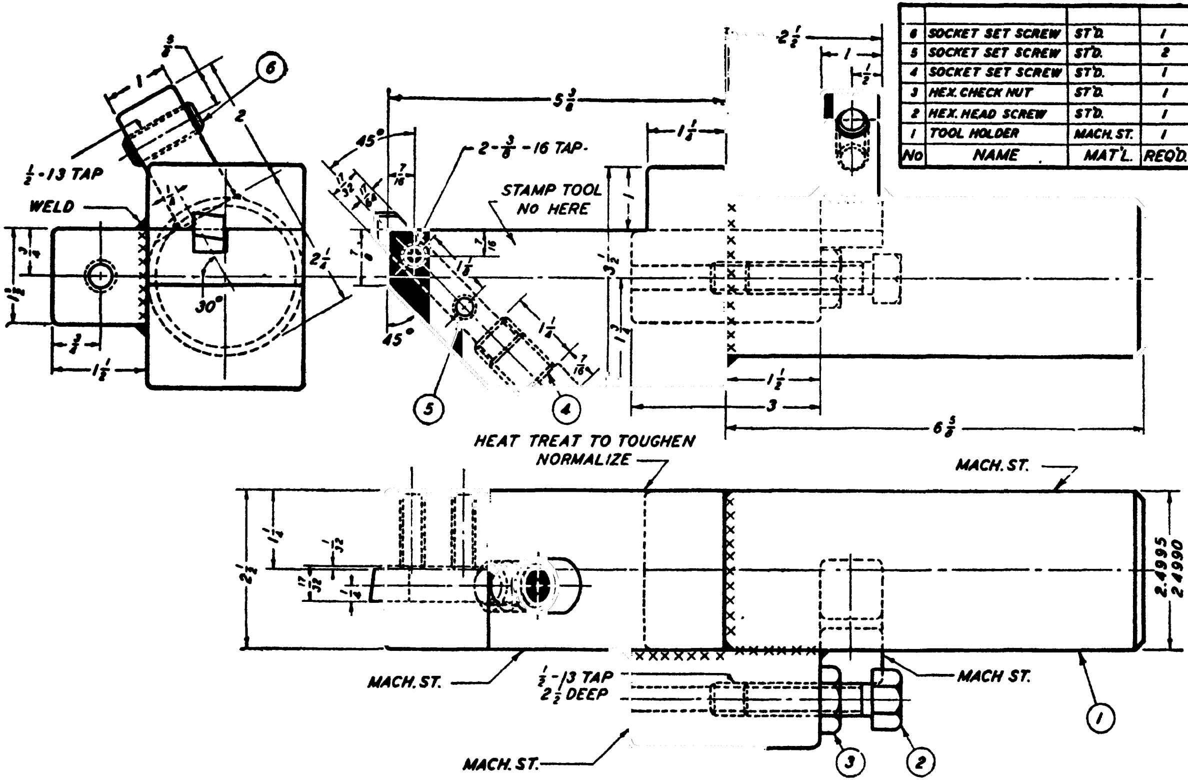
Fig. 46B. Bill of Materials for Boring Bar Shown in Fig. 46A

to the turret lathe of the correct size and type, the operations are numbered, and a tool layout is made.

In tooling a part for production in a turret lathe, a careful analysis is made of the operations required, to see that it is practical to do the work in a machine of this type. Fig. 44 is a steering clutch hub for a track-laying tractor. This part is made of a gray iron casting and must be accurately finished to size. The tool designer makes a layout of the various tools required to machine this part for the operations specified. This tool layout must take into consideration the type of turret lathe that is going to be used, and the number of ports in the turret. On the layout, shown in Figs. 45A and 45B, this machine has five positions in the turret; therefore the tool designer has to take this fact into consideration in designing the tools. This tool layout shows the outline of the piece part so that it can readily be determined how the tools will operate. The piece part is chucked in the machine by means of special jaws that are mounted on the master jaws of the chuck. (These special chuck jaws are shown in the tool layout.) The chief tool designer and production man will go over this tool layout to see if all required operations are covered.

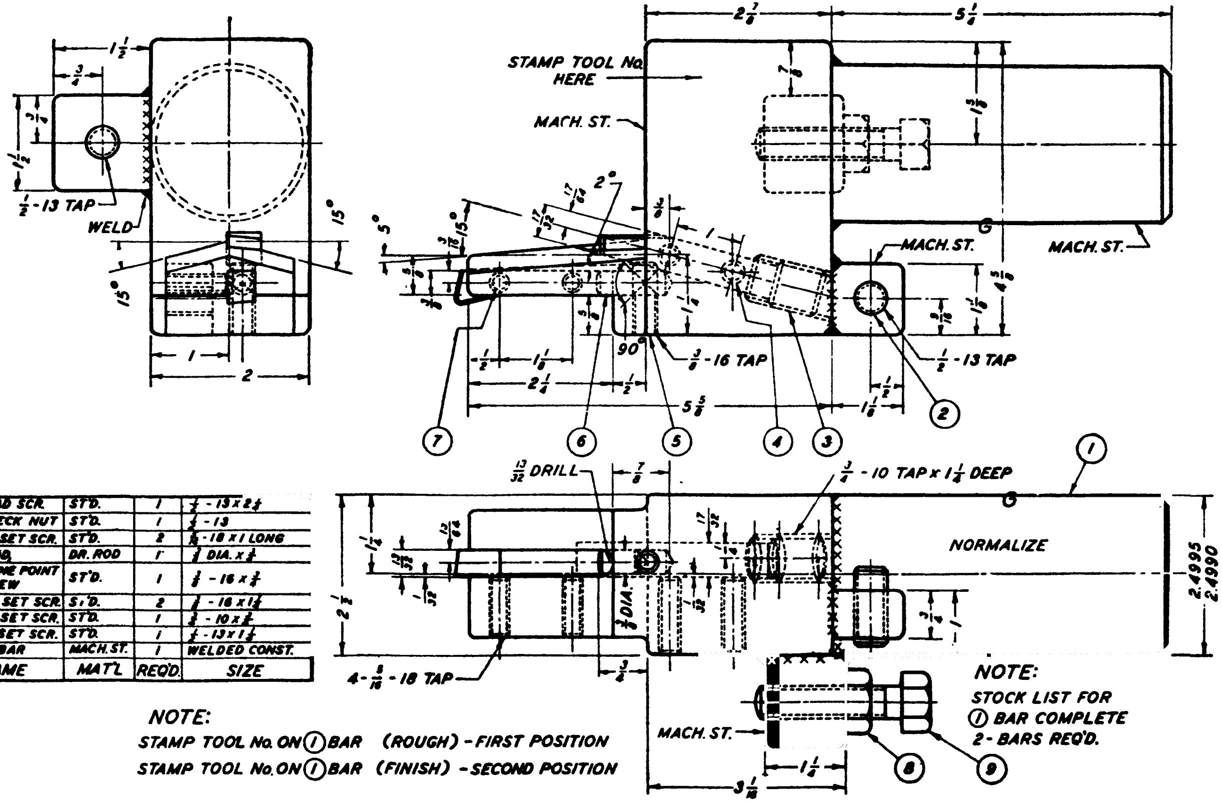
After the tool layout has been approved, the tool designer proceeds with the designing and detailing of individual tools.

First Position. Tools for the first position (see Figs. 46A, 46B, 47, and 48) consist of a single-point boring bar that roughs and counterbores the center bore, and rough faces surfaces *C* and *D* on



6	SOCKET SET SCREW	ST'D.	1	$\frac{1}{2}$-13 x $1\frac{1}{4}$
5	SOCKET SET SCREW	ST'D.	2	$\frac{3}{8}$-16 x $1\frac{1}{4}$
4	SOCKET SET SCREW	ST'D.	1	$\frac{1}{4}$-10 x $\frac{3}{8}$
3	HEX. CHECK NUT	ST'D.	1	$\frac{1}{2}$-13
2	HEX. HEAD SCREW	ST'D.	1	$\frac{1}{2}$-13 x 2
1	TOOL HOLDER	MACH. ST.	1	WELDED CONST.
No	NAME	MAT'L.	REQ'D.	SIZE

Fig. 47. Tool for Rough Turning Surface *A* Shown in Fig. 45A

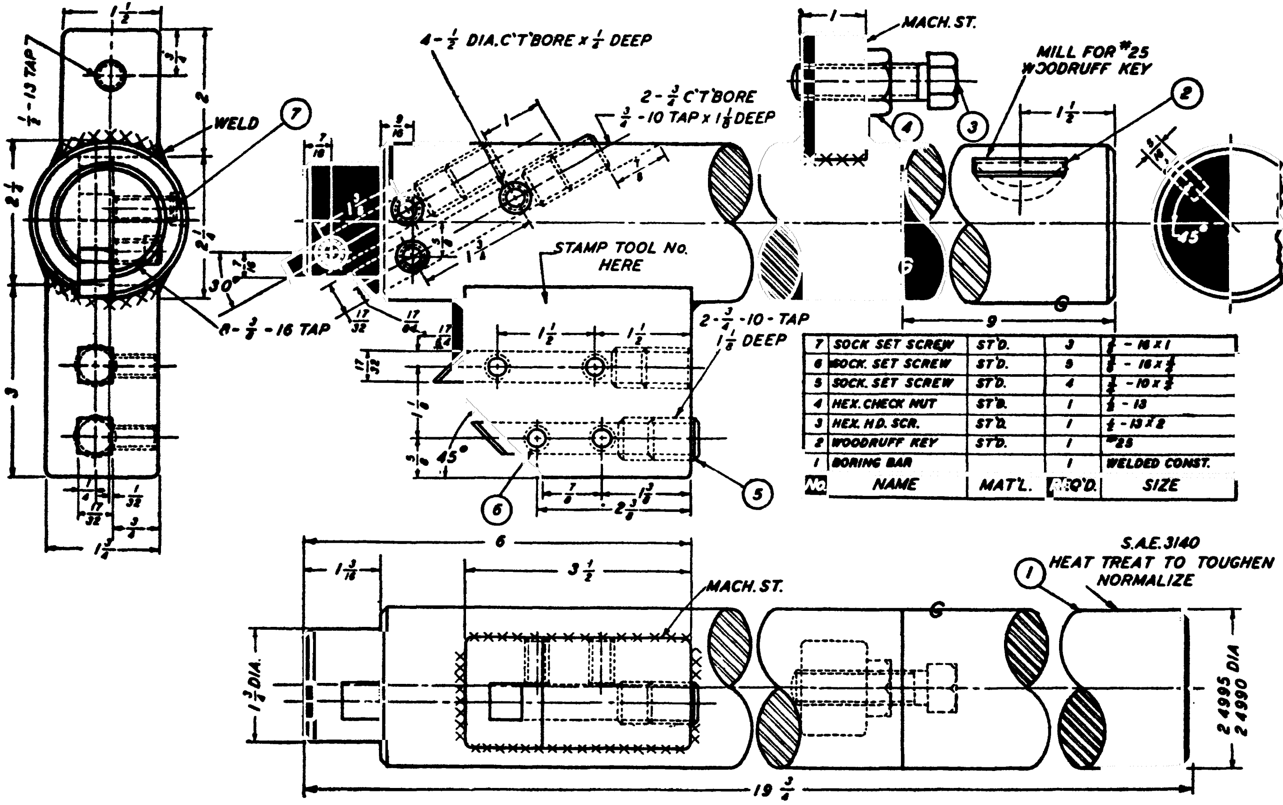


No.	NAME	MAT'L	REQ'D.	SIZE
9	HEX. HEAD SCR.	ST'D.	1	$\frac{1}{2}$-13 x $2\frac{1}{4}$
8	HEX. CHECK NUT	ST'D.	1	$\frac{1}{2}$-13
7	SOCKET SET SCR.	ST'D.	2	$\frac{5}{16}$-18 x 1 LONG
6	PUSH ROD	DR. ROD	1	$\frac{3}{8}$ DIA. x $\frac{7}{8}$
5	SOCK. CONE POINT SET SCREW	ST'D.	1	$\frac{3}{8}$-16 x $\frac{3}{8}$
4	SOCKET SET SCR.	ST'D.	2	$\frac{3}{8}$-16 x $1\frac{1}{4}$
3	SOCKET SET SCR.	ST'D.	1	$\frac{3}{4}$-10 x $\frac{3}{4}$
2	SOCKET SET SCR.	ST'D.	1	$\frac{1}{2}$-13 x $1\frac{1}{4}$
1	BORING BAR	MACH. ST.	1	WELDED CONST.

NOTE:
STAMP TOOL No. ON ① BAR (ROUGH) - FIRST POSITION
STAMP TOOL No. ON ① BAR (FINISH) - SECOND POSITION

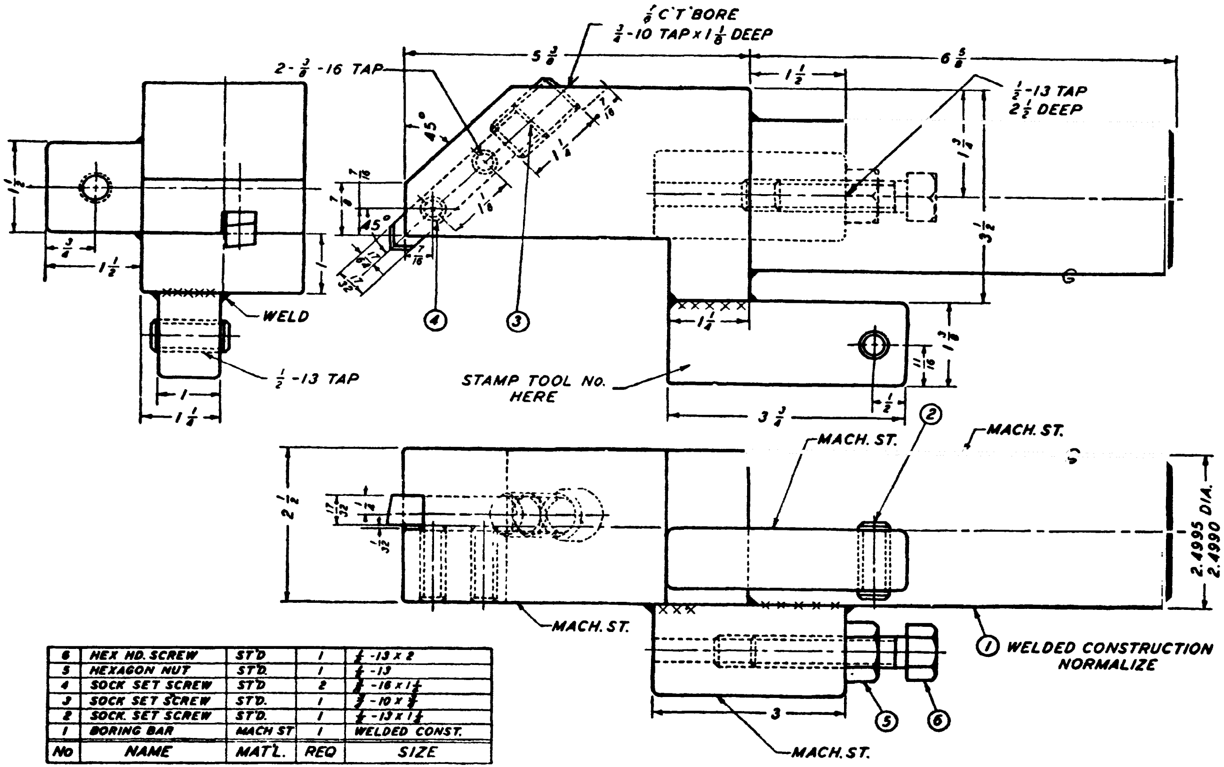
NOTE:
STOCK LIST FOR
① BAR COMPLETE
2 - BARS REQ'D.

Fig. 48. Tool for Rough Turning Surface *B* Shown in Figs. 45A and 45B



No.	NAME	MAT'L.	REQ'D.	SIZE
7	SOCK SET SCREW	ST'D.	3	3/8-16 x 1
6	SOCK. SET SCREW	ST'D.	8	3/8-16 x 3/4
5	SOCK. SET SCREW	ST'D.	4	3/4-10 x 3/4
4	HEX. CHECK NUT	ST'D.	1	1/2-13
3	HEX. HD. SCR.	ST'D.	1	1/2-13 x 2
2	WOODRUFF KEY	ST'D.	1	#25
1	BORING BAR		1	WELDED CONST.

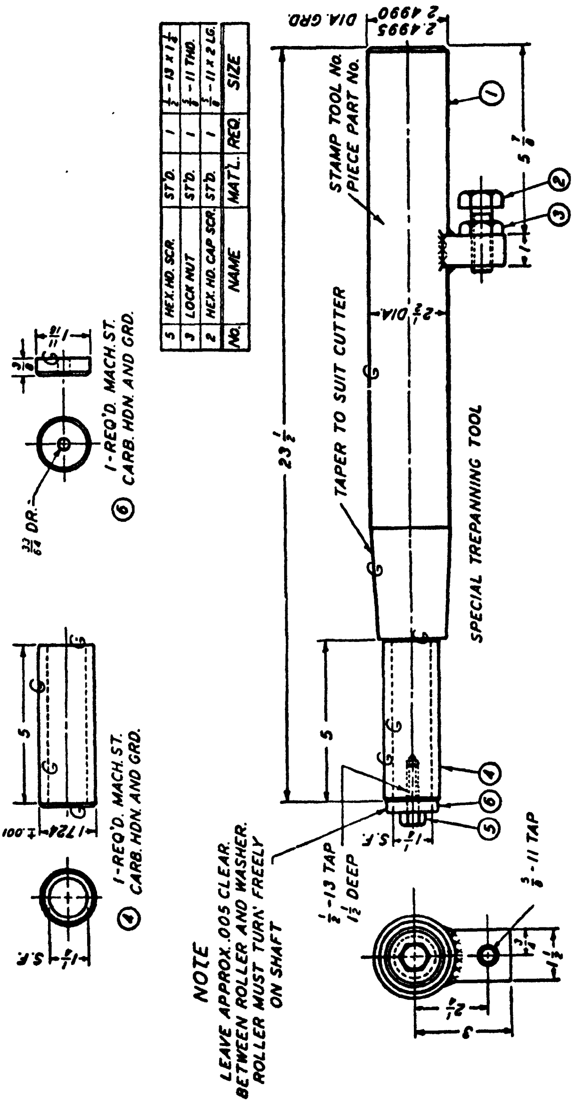
Fig. 49. Design of Boring Bar with Four Chamfering Tools for Use in Third Position of Turret Setup Shown in Figs 45A and 45B



No	NAME	MAT'L.	REQ	SIZE
6	HEX HD. SCREW	ST'D	1	1/2-13 x 2
5	HEXAGON NUT	ST'D.	1	1/2-13
4	SOCK SET SCREW	ST'D	2	3/8-16 x 1 1/4
3	SOCK SET SCREW	ST'D.	1	3/4-10 x 3/4
2	SOCK. SET SCREW	ST'D.	1	1/2-13 x 1 1/2
1	BORING BAR	MACH ST	1	WELDED CONST.

Fig. 50. Tool for Finishing the Outside Diameter of Piece Part. Used in Third Position of the Turret Setup Shown in Figs. 45A and 45B

the internal section of this work piece. The surface *A* is rough turned by a tool shown in detail in Fig. 47. Another separate tool shown



No.	NAME	MAT'L.	REQ.	SIZE
5	HEX. HD. SCR.	ST'D.	1	1/2-13 x 1 1/2
3	LOCK NUT	ST'D.	1	3/4-11 THD.
2	HEX. HD. CAP SCR.	ST'D.	1	5/8-11 x 2 LG.

Fig. 51. Special Trepanning Tool Used in Fourth Position of Turret Setup of Figs. 45A and 45B

in detail in Fig. 48 is used for rough turning surface *B*. You will note from the design of this bar that the details *3* and *4* shown on Fig. 46A are an adjustable stop for setting this bar to the correct

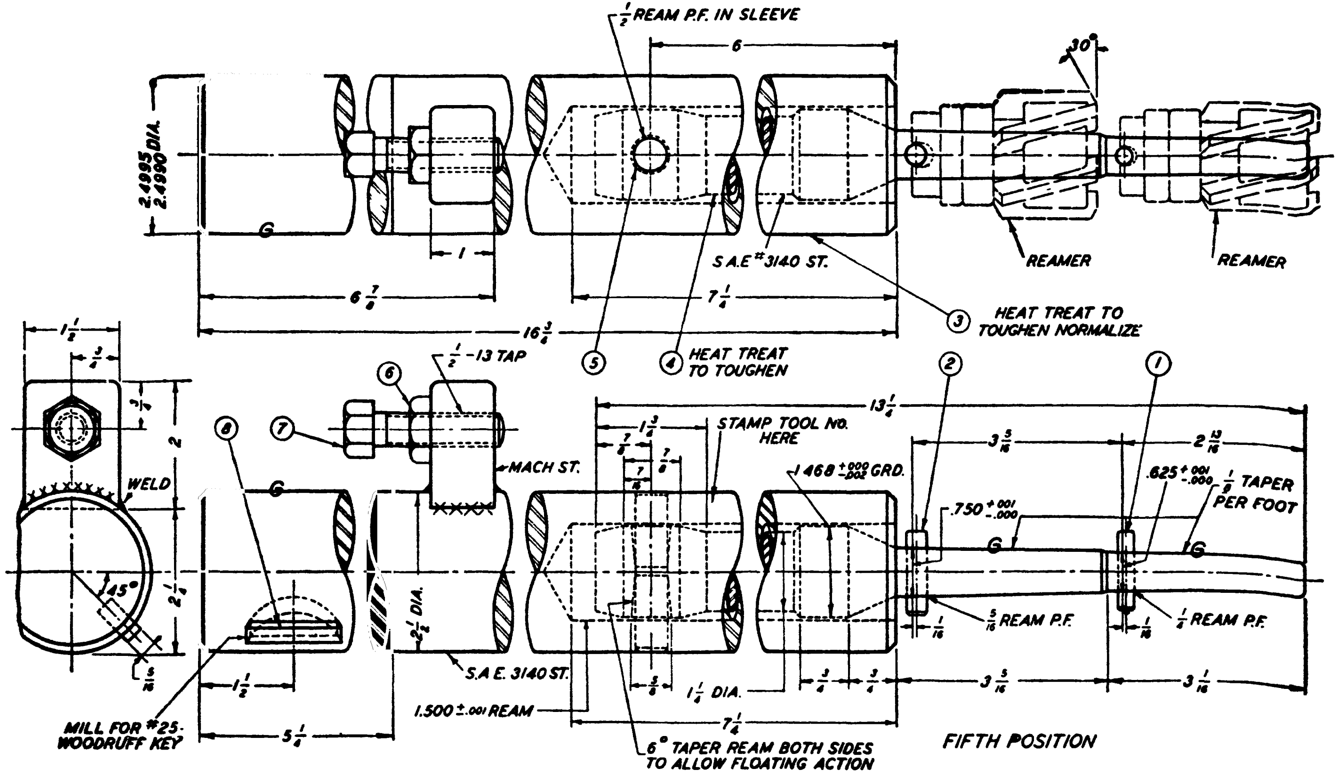


Fig. 52A. Design of Special Floating Reamer Arbor, Used in Fifth Position of the Turret Setup Shown in Figs. 45A and 45B

8	WOODRUFF KEY	STANDARD	1	#25
7	HEXAGON HEAD SCREW	STANDARD	1	$\frac{1}{2}$-13 x 2
6	HEXAGON CHECK NUT	STANDARD	1	$\frac{1}{2}$-13
5	DOWEL	STANDARD	1	$\frac{1}{2}$ DIA x 2$\frac{1}{2}$
4	ARBOR	S A E #3140 ST.	1	1$\frac{15}{32}$ DIA x 13$\frac{1}{4}$
3	SLEEVE	S A E. #3140 ST.	1	WELDED CONST.
2	DOWEL	STANDARD	1	$\frac{5}{16}$ DIA x 1$\frac{1}{4}$
1	DOWEL	STANDARD	1	$\frac{1}{4}$ DIA x 1$\frac{1}{4}$
NO.	NAME	MATERIAL	REQ.	SIZE

Fig. 52B. Bill of Materials for Tool Shown in Fig. 52A

depth of cut. The tool bits are designed so that they can be adjusted individually to obtain the correct dimensions; that is, diameter and depth.

Second Position. The boring bar used in the second position in the turret is like the one used in position *1*; the only difference being that the tool bits are set for the finishing cuts; otherwise, both bars are identical. This design of bar is frequently used in turret lathe practice. Its outstanding advantage is its low first cost, although this design offers some difficulty in resetting tools when it is necessary to regrind them after they have become dull.

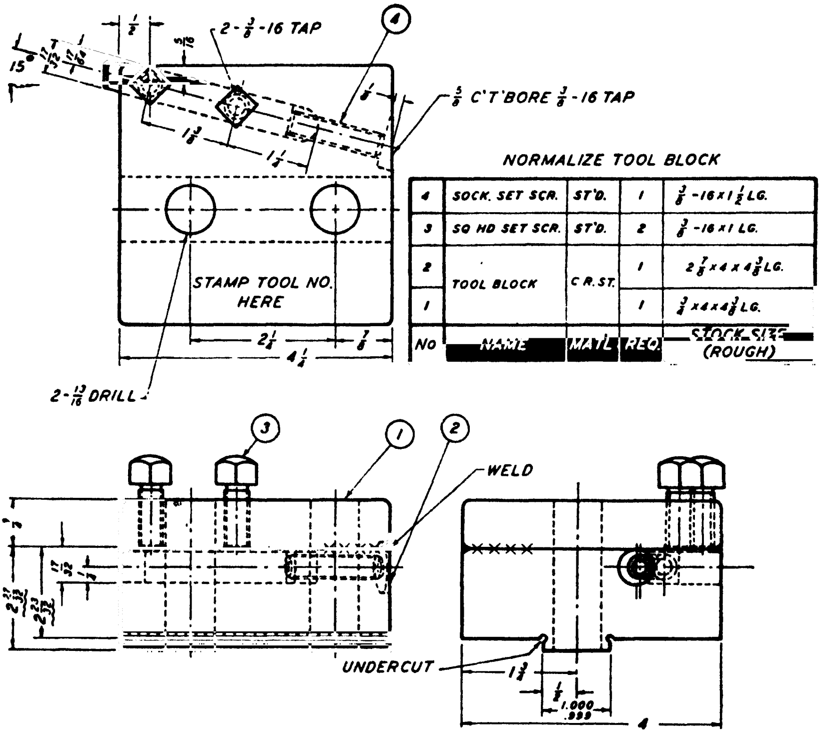
In addition to the bar a single-point tool holder, shown in Fig. 48, is required for finish turning surface *B*. Note the adjustable stop (*8* and *9* of Fig. 48) provided on this holder so that it can be set in the correct position.

Third Position. The third position in the turret requires a boring bar that will chamfer the various sections on the work piece where these operations are called for. There are four chamfering tools mounted in this bar. These tool bits are provided with adjustments and means for locking them in position. Fig. 49 illustrates this tool. This design of bar is very efficient and is one of the best means of performing chamfering operations on work of this kind.

Fig. 50 shows details of a tool used in this position for finishing the outside diameter of this piece part. The design is somewhat similar to the other tool holders described.

Fourth Position. For machining the bottom section on the inside of this work piece, a special trepanning tool holder, Fig. 51, is used in the fourth position of the turret. This special trepanning tool is made with two inserted blades which are adjustable so that they can be reset and reground when they become dull. This type of tool finishes the inside recess or grooves.

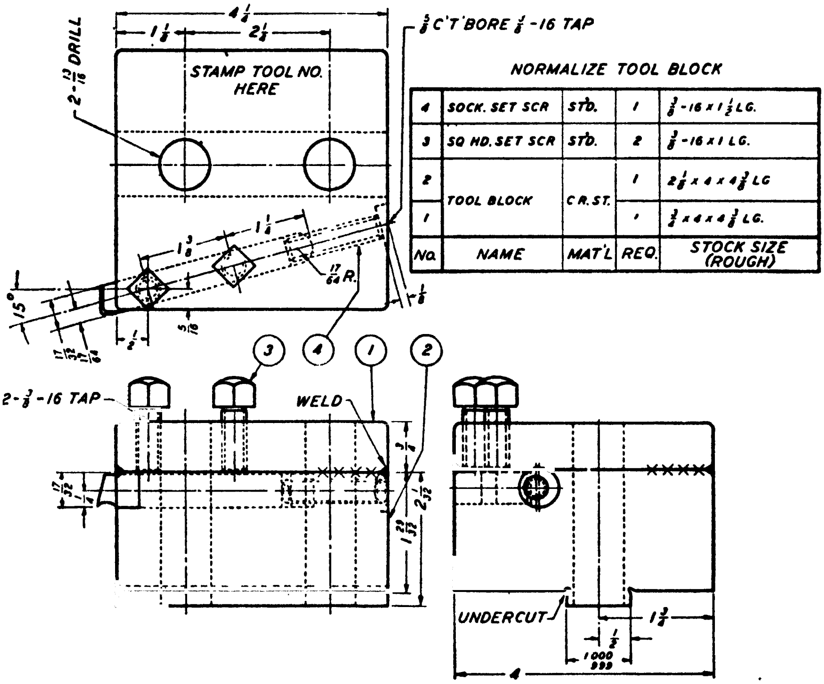
Fifth Position. Figs. 52A and 52B illustrate the design of a special floating reamer arbor. This arbor has been designed so as to permit the multiple flute reamers to align themselves with the previously bored holes. Fig. 52A clearly shows the design of this floating section of the reamer arbor.



4	SOCK. SET SCR.	ST'D.	1	3/8-16 × 1 1/2 LG.
3	SQ HD SET SCR.	ST'D.	2	3/8-16 × 1 LG.
2	TOOL BLOCK	C R. ST.	1	2 7/8 × 4 × 4 3/8 LG.
1			1	3/4 × 4 × 4 3/8 LG.
NO	NAME	MAT'L	REQ.	STOCK SIZE (ROUGH)

Fig. 53. Front Tool Block to Rough-Face Steering Clutch Hub Shown in Fig. 44

Figs. 53 and 54 illustrate the tool blocks for the front and rear cross slides. These tool blocks rough and finish the face of the work piece. You will note from the design of these blocks that each is made in two sections. The lower section has a slot milled in it to accommodate the tool bit. Attention is called to the wavy lines which appear under the two dimensions at the left of the lower section on Fig. 53. These lines indicate that the dimensions are correct and are to be followed, although they were not used in the drawing. The cover plate is welded in position ,and clamps the tool bits. This is very good construction and it is much simpler to design a tool block in this way than to have the slots completely through a solid block of steel. This is a typical turret lathe tool design and the one most frequently found in the average metal-working plant.



No.	NAME	MAT'L	REQ.	STOCK SIZE (ROUGH)
4	SOCK. SET SCR	STD.	1	3/8-16 x 1 1/2 LG.
3	SQ HD. SET SCR	STD.	2	3/8-16 x 1 LG.
2	TOOL BLOCK	C.R.ST.	1	2 1/8 x 4 x 4 3/8 LG
1			1	3/4 x 4 x 4 3/8 LG.

Fig. 54. Rear Tool Block to Finish-Face the Piece Part Shown in Fig. 44

TOOL BLOCKS

A wide variety of tool blocks can be designed for use on automatic turret lathes and special double-end machines. Fig. 55 illustrates a multiple tool block for an automatic lathe. This block consists of three parts: the body, the cover plate, and the back-up screw block. By referring to Fig. 55 it will be noted on the left-hand side of this drawing that a layout has been made of the work piece, and tools are shown, consisting of two flat grooving tools, a flat form tool that cuts a groove and chamfers the shoulder on this

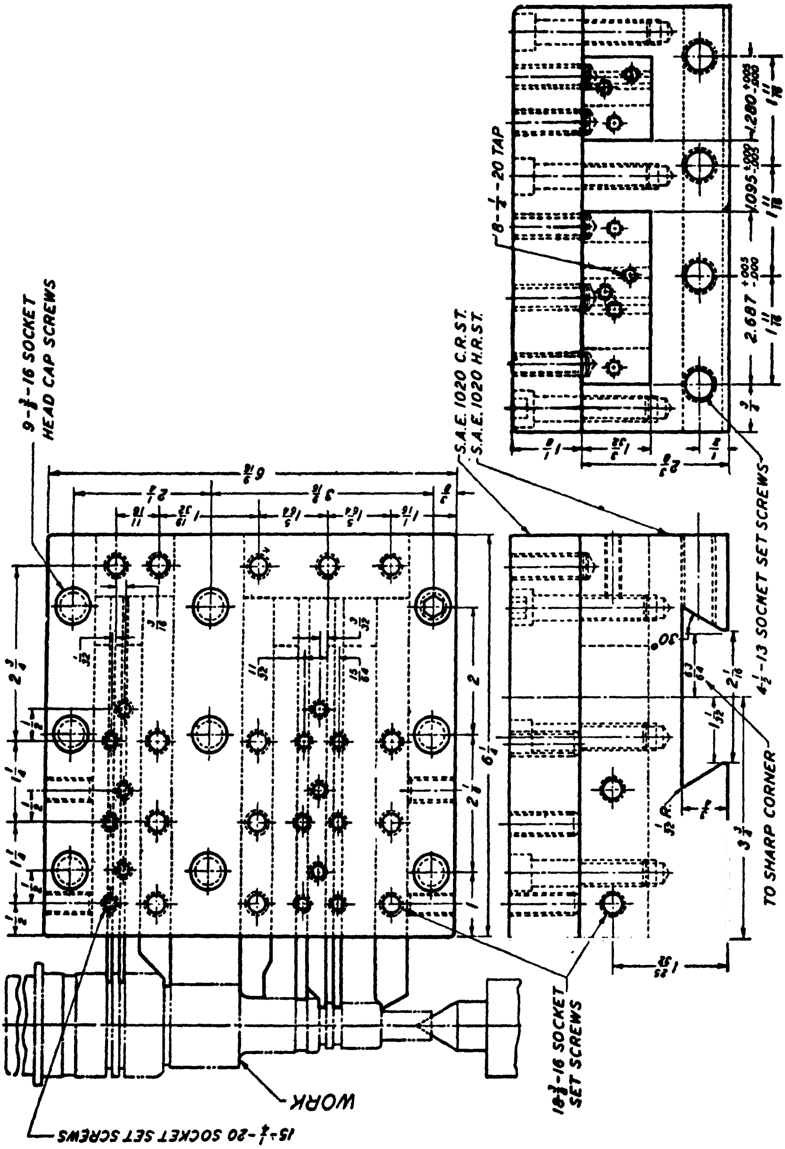
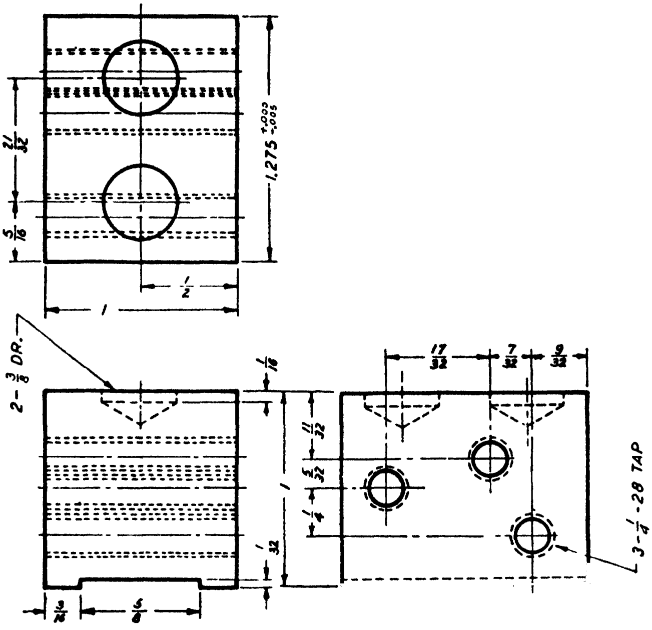


Fig. 55. Multiple Tool Block for an Automatic Lathe

work piece (which is a shaft). Another forming tool is furnished for machining a radius, then tools for grooving and chamfering, and an additional form tool. By use of this combination of tools it is possible to machine all the required dimensions and steps by feeding this tool block at right angles to the work piece. This type of block has been designed with a dovetail to match the dovetail on the rear



MATERIAL S.A.E. #-1020 C.R.STEEL
1-REQ'D.

Fig. 56. **Back-up Screw Block for the Design Shown in Fig. 55**

slide of the automatic lathe. On one side of this dovetail, four ½″-13 thread holes have been drilled and tapped for socket set screws which clamp the tool block in the correct position on the rear cross slide. It will be noted from the design that the slots for the tools are milled entirely through the base of the tool block. For mounting the cover plate, 9 holes are drilled and tapped for ⅜″-16 socket head cap screws, and a section at the rear of the tool block has been milled to provide for the insertion of the back-up screw blocks which are shown by Figs. 56 and 57. These back-up screw blocks are mounted in the base of the tool block by means of five socket set screws. Back-up screws are used to prevent the various cutting tools from slipping away from the work due to the pressure of the cut. This is a very good design where it is required to have an accurate tool block, as it can be disassembled easily and in the event any inaccuracies develop, due to wear, these can be corrected by the use of shims or by remachining.

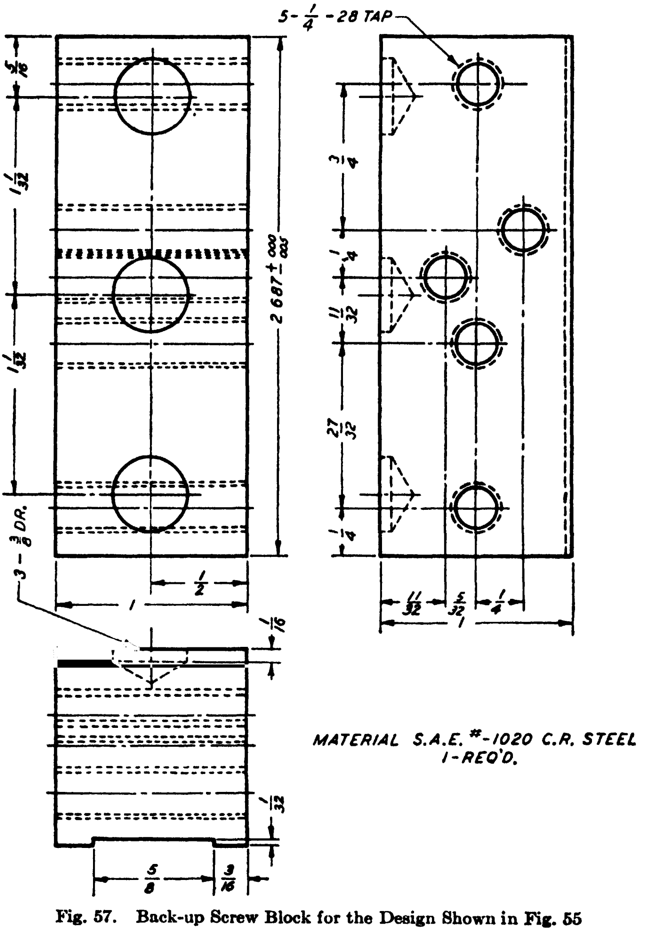


Fig. 57. Back-up Screw Block for the Design Shown in Fig. 55

Fig. 58 is a layout of tool blocks machining a work piece in an automatic lathe. These tool blocks are somewhat similar to Fig. 55, but the construction is different in that these tool blocks do not have inserted back-up blocks for the reason that a section of the block itself is milled away and it is very simple to insert back-up screws through the rear portion of the tool blocks. In the design it will be noted that the six tools on the front tool block are for machining various steps and dimensions required on the outside diameter of this work piece, and this block has a longitudinal feed from right to left. The rear tool block feeds in at right angles to the axis of the work, and forming, chamfering, grooving and facing tools complete the work piece. The flat form tools in the rear tool block are of a double-end design; that is, the forms are machined in both ends of these flat tools, so that if one end becomes dull it is only necessary to reverse the tool in the tool block and continue machining. When both ends have become dull, the flat forming tool is exchanged for a new tool that has been ground ready for use.

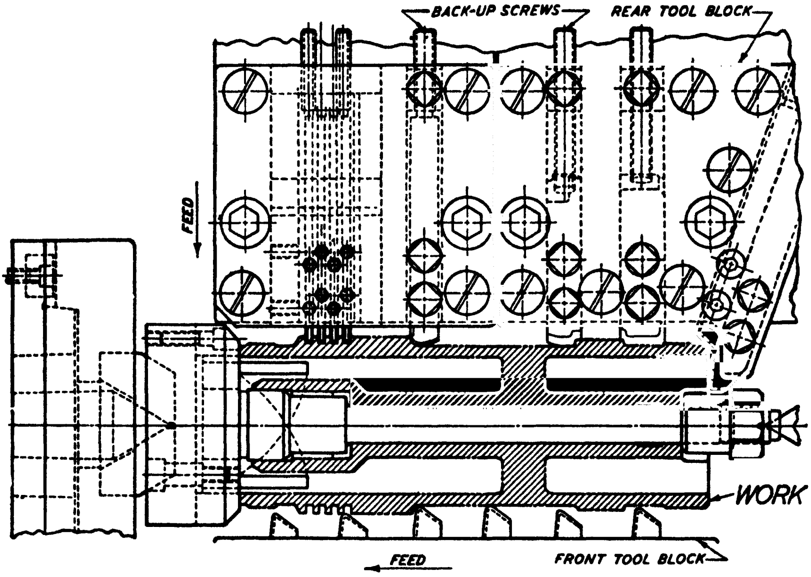


Fig. 58. Layout of Tool Blocks Machining a Piece Part in an Automatic Lathe

DOUBLE-END FLAT FORMING TOOLS

Considerable time can be saved on machining operations by using a double-end flat forming tool. Fig. 59 illustrates such a tool designed to be used with a suitable holder. This type of tool is somewhat similar to a circular forming tool; that is, both ends of the flat forming tool are carefully machined and ground, and to resharpen a tool of this type it is only necessary to grind it on the top. This prevents any change in the form or contour of the tool. In using a tool of this type, resetting the tool to suit the work will compensate for the amount ground off on the top of the tool. This type of tool, either in a tool holder or in a tool block, will have increasing use, due to the fact that little time is lost in resharpening tools.

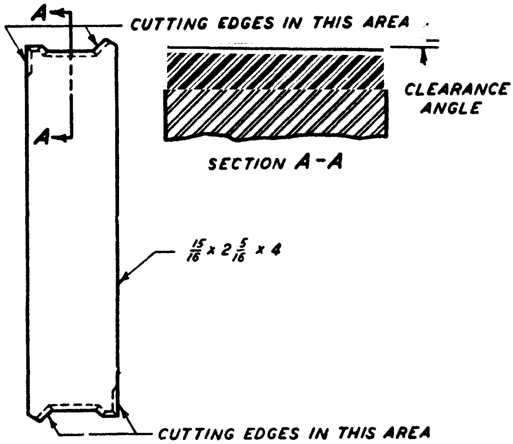

A
CUTTING EDGES IN THIS AREA
CLEARANCE ANGLE
A
SECTION A-A
$\frac{15}{16} \times 2\frac{5}{16} \times 4$
CUTTING EDGES IN THIS AREA

Fig. 59. Double-End Flat Forming Tool

TOOL HOLDERS

A method of holding a flat forming tool is shown by Fig. 60. This is a simple design of flat forming tool, and the holder is made with an angle to accommodate the angle on the back of the tool. A groove is machined in the side of the tool to accommodate the clamping screw. This type of holder permits rapid adjustment of the tool.

On automatic lathes and screw machines it is desirable in many instances to have the cutting tool mounted on the rear cross slide. This type of tool holder permits a cut to be taken on the upward rotation of the work piece instead of at right angles to the axis of the work piece. Fig. 61 illustrates a tool holder of this type. The flat forming tool is made with a dovetail to fit in the dovetail groove of a tool block. This section in the tool block has a slot milled

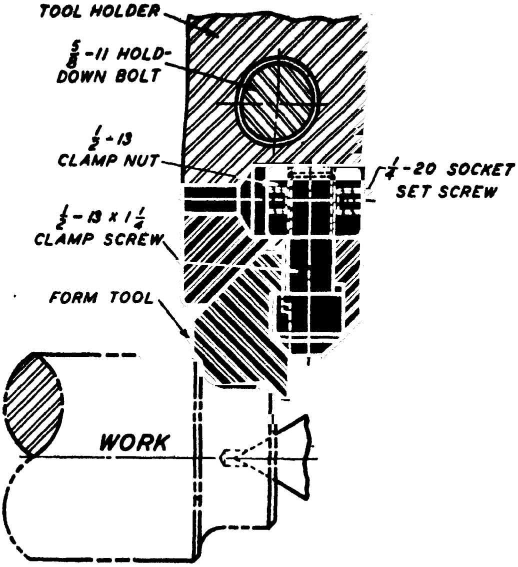

TOOL HOLDER
$\frac{5}{8}$-11 HOLD-DOWN BOLT
$\frac{1}{2}$-13 CLAMP NUT
$\frac{1}{4}$-20 SOCKET SET SCREW
$\frac{1}{2}$-13 x 1$\frac{1}{4}$ CLAMP SCREW
FORM TOOL
WORK

Fig. 60. Tool Holder for Flat Forming Tool

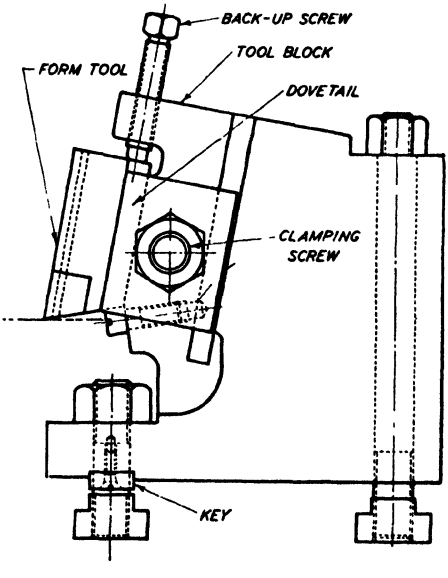


Fig. 61. Tool Holder for Mounting on the Rear Cross Slide of an Automatic Lathe or Screw Machine

through it, and a clamping screw is inserted in this portion of the block to clamp the tool in the correct position. The back-up screw is provided at the top of the block to prevent the tool from moving out of adjustment. This design of tool holder permits rapid adjustment of a cutting tool so that it can be used for various diameters of work. The tool holder is located in the cross slide by means of keys similar to those on a milling fixture.

For holding circular forming tools, a holder similar to Fig. 62 has been designed. This type of holder is used to hold two circular forming tools that have serrations on the side of the cutter, serrations which are radial from the center bore of the tool. The matching serrations are machined on an adjusting arm in the tool holder.

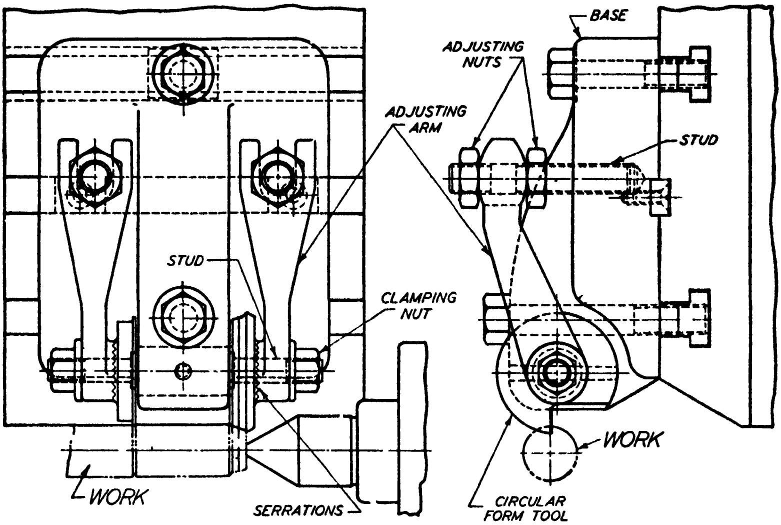


Fig. 62. Tool Holder for Circular Forming Tool

Each circular form tool is clamped to the base of the holder by means of a stud and clamping nut. Each tool has an adjusting arm which is mounted to the tool-holder base by means of a stud and adjusting nuts which are located on the stud above and below the adjusting arm. Circular forming tools on a tool holder of this kind can always be adjusted to the center of the work piece by loosening the clamping nut on the stud on which the circular forming tool is mounted, and then adjusting the arm. In this illustration is shown a pair of such tools for machining the groove and the end of a shaft. This same design can also be used for one or several circular forming tools if it is desired

TOOLS FOR SPECIAL PURPOSE MACHINES

It is sometimes a real problem to design tools to produce pipe fittings in the large quantities required Fig 63 illustrates an elbow pipe fitting, or what is sometimes termed an *ell* This photograph shows the rough forging and the finished elbow Another type fitting that is also required in large quantities is the *tee* Fig 64 illustrates the rough forging and a finished tee and, due to the fact that these are produced in the various pipe sizes, it is desirable to have a machine with a fixture that is capable of handling all of these various sizes

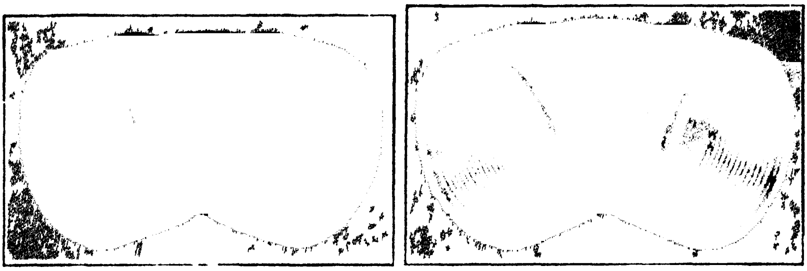


Fig 63 Elbow Pipe Fitting, or Ell, of Forged Steel Left, Rough Forging, Right, Finished Elbow

Courtesy of W F & John Barnes Co, Rockford Ill

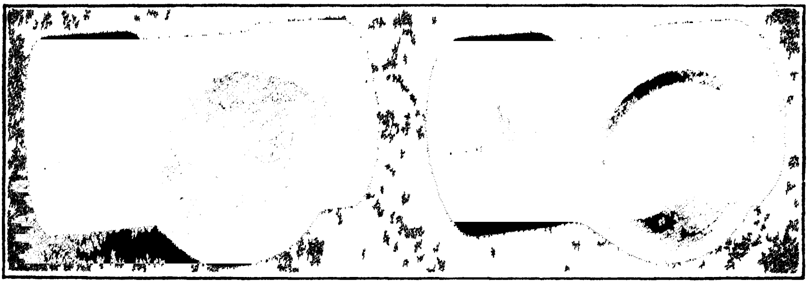


Fig 64 Forged Steel Pipe Tee Left Rough Forging Right Finished Tee

Courtesy of W F & John Barnes Co, Rockford Ill

These particular ells and tees are made from solid steel forgings

This means that a considerable quantity of metal must be removed. but the bores must be in perfect alignment and clean threads are absolutely essential; that is, the threads must be correct in angle and with commercial tolerance on lead, and there cannot be any ragged tears on the sides of the thread angle. These forged tees and ells for high-pressure hydraulic and steam applications are produced in sizes from ½″ up to and including 2″ pipe size. Some of these tees and ells are made so that they are of the slip-on type; that is, they are slipped over the pipe and then welded into place. These are drilled, core drilled, counterbored and faced The screwed type pipe fittings are drilled, core drilled, taper reamed, chamfered, and tapped to the correct thread size The machine for producing these parts is illustrated by Fig. 65

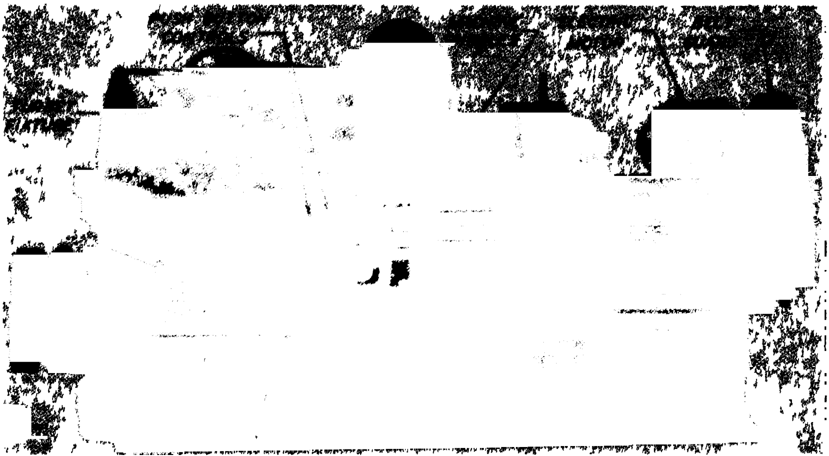


Fig. 65. Special Multiple-Spindle Hydraulic Machine for Drilling and Tapping Forged Steel Pipe Fittings

Courtesy W F & John Barnes Co , Rockford, Ill

The main design factor contributing to the required accuracy in drilling and tapping is the work-holding fixture on this machine. The tees and ells are not relocated between the machine operations, but are indexed in a turret type fixture mounted on an indexing drum. This design permits machining of the fittings without unclamping and relocating the work, thereby producing opposite bores in the same plane and in exact right angles to one another. The fixture on this machine is of the trunnion type and consists of four

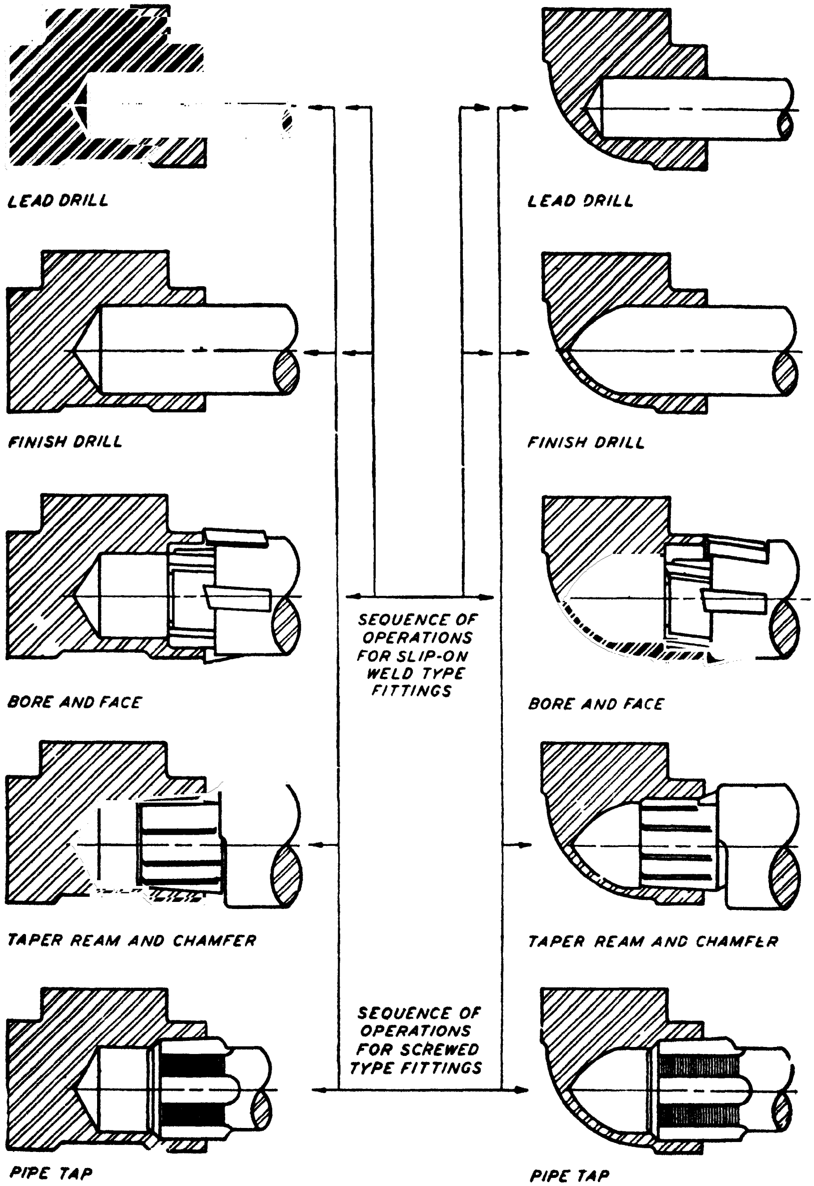


Fig. 66. Sequence of Operations to Finish Pipe Fittings

stations that are hydraulically indexed. It has a turret for holding four fittings mounted on each one of the four stations. After the trunnion fixture is indexed, the turret is manually indexed so that one completely machined fitting is unloaded with each index of the trunnion fixture. These parts are held in the turret fixture by means of replaceable form jaws. The jaws of course must be made to fit the particular size of tee or ell that is being machined. The design of the jaws is such that either a tee or ell of the same size can be held with the form jaw. This is another very good example of the use of jaws for holding work.

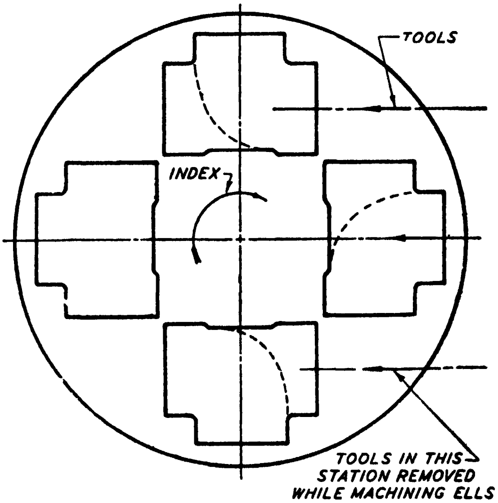
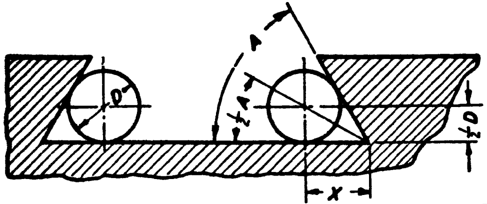


Fig. 67. View of Turret Fixture. Four of These Are Mounted on an Indexing Drum

Fig. 66 illustrates a sequence of operations. The slipon type of pipe fittings requires only three operations to complete the part. The screwed type fittings require four operations to finish the part.

Fig. 67 is a plan view of the turret fixtures. Four of these fixtures are mounted on the indexing drum on the machine. When machining ells, tools are removed from one of the stations. This same principle of design and tooling can be followed out on other types of work and there is a trend towards design of machines and tools of this character. It is well for the tool designer to give considerable thought to designing tools for special single-end and double-end machines for high-production work.

Dimensions of Dovetail Angles



The table gives values of *X* without calculation. Example showing use of table: Angle *A* = 60 degrees, and diameter *D* = 5/8 inch. To find dimension *X*, locate the size *D* of the rod in the column at the left, and on the same line in the column headed *60* degrees, dimension *X* is found to be 0.54125 inch.

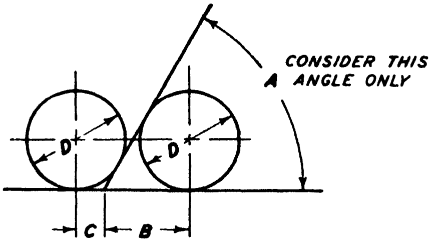
Dia. of Rod *D* Inches	Angle *A*, Degrees												
	75	70	65	60	55	50	45	40	35	30	25	20	15
	Dimension *X*, Inches												
1/16	.04072	.04462	.04905	.05412	.06003	.06701	.07544	.08585	.09911	.11662	.14096	.17722	.23756
1/8	.08145	.08925	.09810	.10825	.12006	.13403	.15088	.17171	.19822	.23325	.28191	.35445	.47473
3/16	.12217	.13388	.14715	.16237	.18009	.20104	.22633	.25757	.29733	.34987	.42287	.53168	.71209
1/4	.16290	.17851	.19621	.21650	.24012	.26806	.30177	.34343	.39645	.46650	.56383	.70891	.94946
5/16	.20362	.22314	.24526	.27062	.30015	.33507	.37721	.42929	.49556	.58312	.70479	.88614	1.18682
3/8	.24435	.26776	.29431	.32475	.36018	.40209	.45266	.51515	.59467	.69975	.84575	1.06336	1.42419
7/16	.28507	.31239	.34337	.37887	.42021	.46910	.52810	.60101	.69378	.81637	.98671	1.24059	1.66165
1/2	.32580	.35702	.39242	.43300	.48025	.53612	.60355	.68687	.79290	.93300	1.12767	1.41782	1.89892
9/16	.36652	.40165	.44147	.48712	.54028	.60314	.67899	.77273	.89201	1.04962	1.26863	1.59505	2.13629
5/8	.40725	.44628	.49053	.54125	.60031	.67015	.75443	.85859	.99112	1.16625	1.40959	1.77228	2.37365
11/16	.44797	.49090	.53958	.59537	.66034	.73717	.82988	.94445	1.09023	1.28287	1.55055	1.94950	2.61102
3/4	.48870	.53553	.58863	.64950	.72037	.80418	.90532	1.03031	1.18935	1.39950	1.69151	2.12673	2.84838
13/16	.52942	.58016	.63769	.70362	.78040	.87120	.98076	1.11617	1.28846	1.51612	1.83247	2.30396	3.08575
7/8	57015	.62479	.68674	.75775	.84043	.93821	1.05620	1.20203	1.38757	1.63275	1.97343	2.48118	3.32311
15/16	.61087	.66942	.73579	.71187	.90046	1.00523	1.13165	1.28789	1.48668	1.74937	2.11439	2.65842	3.56048
1.000	.65160	.71405	.78485	.86600	.96050	1.07225	1.20710	1.37375	1.585[illegible]	1.86600	2.25535	2.83565	3.79785

Fig. 68

DOVETAILS

In designing jigs and fixtures for certain types of machine tools it is necessary to provide a dovetail on these fixtures to fit into the dovetail on the table of the machine. This is especially true of tools for certain types of turret and automatic lathes. Ordinarily it requires considerable time to figure out the angles of these dovetails. Fig. 68 is a table that eliminates figuring of these dovetail angles; by using this the tool designer can save time and effort.

Constants for Calculating Dovetails



Angle A	To Find B: Multiply D by	To Find C: Multiply D by	Angle A	To Find B: Multiply D by	To Find C: Multiply D by
30°	1.86602	.13397	60°	.86602	.28867
35°	1.58579	.15767	65°	.78484	.31853
40°	1.37374	.18198	70°	.71407	.35011
45°	1.20711	.20711	75°	.65161	.38366
50°	1.07225	.23315	80°	.59587	.41955
55°	.96049	.26028			

Fig. 69

To find the angle of external dovetails, the table shown on Fig. 69 is used. By means of these constants, dimensions required for the laying out of proper dovetails can be determined readily.

QUIZ QUESTIONS

1. How many tool ports are carried on the turret of an automatic screw machine and how are the positions controlled?

2. How are the turret and the cross slide moved to and from the work in the automatic screw machine?

3. What is the outstanding advantage of circular forming tools?

4. Why is it essential that the tool designer be familiar with the standard tools available for automatic screw machines?

5. The balance turning tool and the swing tool illustrated in Fig. 3 generally are used on what type of work?

6. When using a circular form tool having two or more diameters, why is it that the difference in the radii of the steps on the tool will not correspond exactly to the difference in the steps on the work?

7. What are some of the control features of automatic lathes?

8. What are some of the special features of the tooling layout shown in Fig. 15?

9. What are some of the features of the tool blocks illustrated in Figs. 17 and 18?

10. What is the driving mechanism for the turning and forming of the bicycle hub illustrated in Figs. 22 and 23? What are its advantages?

11. Name some of the types of chucks and chuck jaws used on turret and automatic lathes.

12. What factors must be considered in the design of chuck jaws?

13. What are the sizes of standard chucks for automatic lathes, mills, and turret lathes?

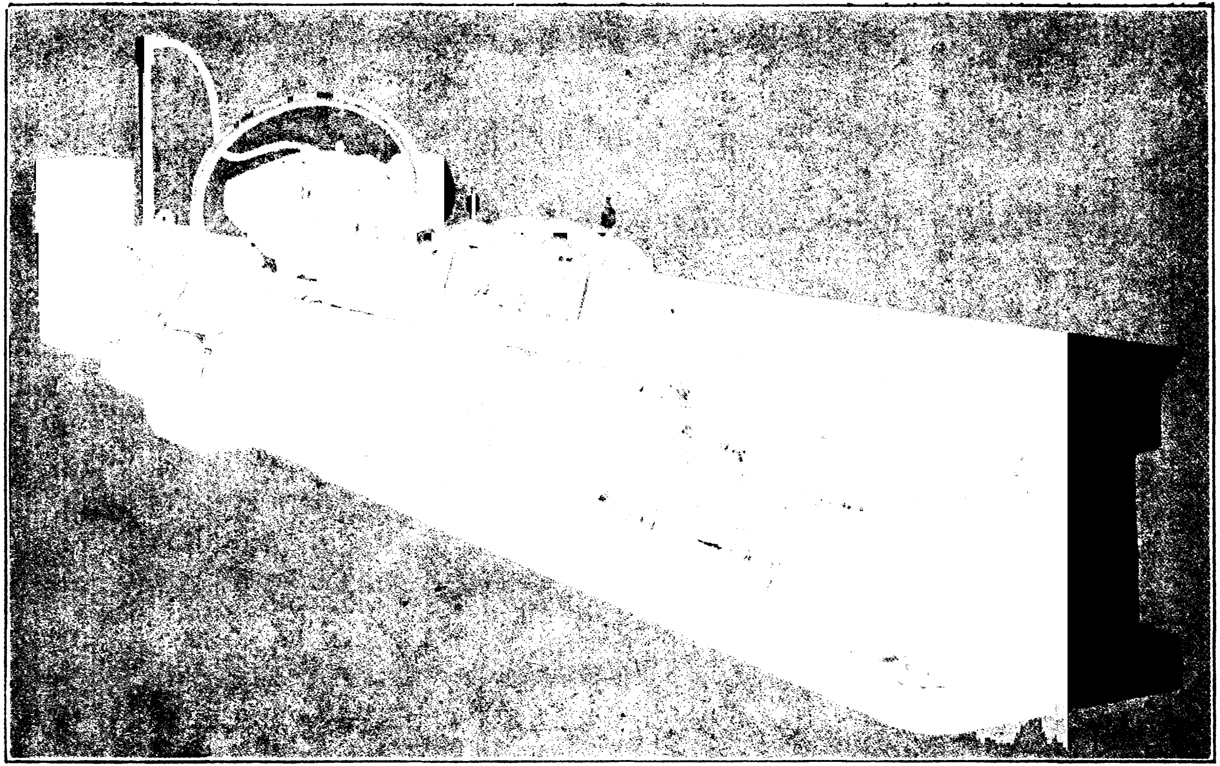
14. What are some of the special features of the chuck illustrated in Fig. 33?

15. In designing tools for either bar or chucking machines, what important point must the designer keep in mind?

16. In tooling for production in a turret lathe, what are some of the important factors the designer must consider?

17. What are some of the special features in the tool block illustrated in Fig. 55?

18. How does the design of the work-holding fixture contribute to the speed and accuracy of production of the elbow pipe fitting shown in Fig. 63?



HORIZONTAL HONING MACHINE USED IN THE MANUFACTURE OF FIELD ARTILLERY

Courtesy of W. F. & John Barnes Co., Rockford, Ill.

DRILL JIGS

Standard interchangeable parts so common today in manufacturing would be almost impossible without the use of drill jigs. The term "jig" has often been misused; for example, in welding operations, fixtures are sometimes termed welding jigs. A jig is a work-holding device generally used in a drill press in conjunction with drill bushings for guiding the tools so that drills will produce holes only where the bushings are located in the drill jig. The body of the jig is designed and made so that the piece part is definitely located in the same position each time the drill jig is used. Therefore, a piece part that is drilled in a drill jig will be identical with all the other parts that are produced in the same drill jig.

Certain principles of jig design have been developed over a period of years and have become common practice. These principles are more or less standard in all manufacturing plants, although new developments are constantly being introduced due to manufacturing conditions.

The designer must give consideration to numerous points in designing a drill jig. First, the tolerance or degree of accuracy of the part; this oftentimes determines the type of jig to be used. The number of sides of the part to be drilled may determine the type of jig; in some cases a box jig would be used where a part (such as a casting) is to be drilled on four or six sides. On some large parts an indexing jig would be designed on account of the excessive weight of the part and the jig itself. In some cases the number of parts to be produced determines the type of jig that would be made; if only a few hundred parts were to be produced, a simple plate jig would be designed and made; if on the other hand several thousand parts were to be produced, a quick-acting jig would be necessary. The tool designer must keep in mind at all times the fact that for a small number of parts, except in unusual instances, the tool cost must be correspondingly low; when large quantities of parts are to be machined, the tool expense can be higher by reason of the fact that the increased cost would be distributed over a large number of pieces, making the unit cost very low.

Therefore, in designing drill jigs the following points must be remembered:

First. Locate the work accurately and quickly.

Second. Prevent the work from being inserted in the jig in any other way than the correct position.

Third. Prevent spring or movement of the piece during the drilling operation.

Fourth. Have ample chip clearance and design the jig so that it can be cleaned readily and easily.

Fifth. It must be as strong as possible without undue weight.

Sixth. The drill jig should be designed so that there are no loose parts that may be lost easily.

Seventh. The design should be as simple as possible so the jig will not easily get out of order.

The designer should make full use of all the various standard items which are commercially available and that go into the manufacture of drill jigs; by doing so, the cost of designing and building is considerably reduced.

For some piece parts there is a wide choice as to the type of jig that could be designed. The method of clamping should be positive and the clamps should have sufficient strength to hold the work firmly in the body of the jig. In most instances the designs discussed in this work illustrate the fundamental principles of drill jig design, but the designer should see that the piece part is properly located in the jig by placing locating pins, rest pads, stops, or **V**-blocks in the correct positions in the drill jig body.

A definite location point should be provided in each drill jig so that each piece part loaded into the jig will be located in the drill jig in the same manner. However, in some instances the piece part is made from a rough casting that has not been machined prior to coming to the drill jig operation, and in this case the jig should be provided with adjustable locators of some type that will compensate for the inequality of the surface of the piece part. Usually on jobs of this kind the subsequent operations are located from the drilled or reamed holes in the piece part. It is desirable in designing drill jigs to see that the piece part is held in the jig body by some positive means so as to prevent the piece part from slipping when the drilling operations are being performed. Various means are used to clamp piece parts in jigs and the designer, by studying the available means, can usually select the right type for the jig.

In designing drill jigs the first thing to be done is to study the piece part carefully and consider the other factors that have been mentioned. When he has finally decided what type of drill jig should be used, the designer checks to see the type of drill press that is available for the job. After this, he proceeds with the design of the jig.

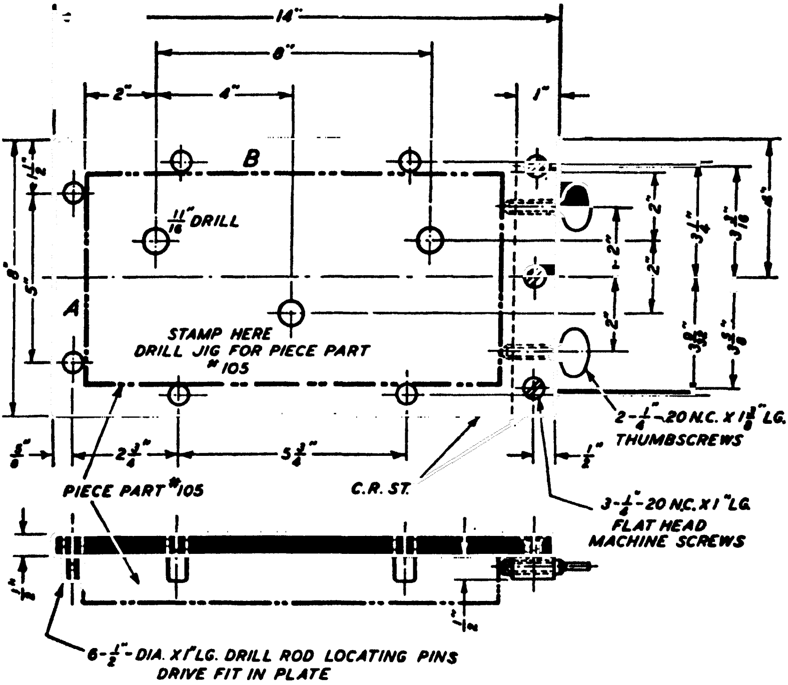
PLATE DRILL JIGS

The simplest form of drill jig is the ordinary plate type jig, Fig. 1A. This type of jig is usually designed where there are only a few parts to be produced. The piece part shown in Fig. 1B is of cold-rolled steel plate, 6″ wide by 12″ long by 1″ thick. There are three $^{1}/_{16}$″ holes to be drilled in this part. The design shown by Fig. 1A consists of a ½″ steel plate with a number of pins that definitely locate this piece part in the jig. The drill jig is clamped to the piece part by means of thumb screws. No drill bushings are used in this jig because the accuracy of the piece part does not require any close limits and the ordinary tolerance on these three holes due to the fractional dimensions would be plus or minus .005″

In the event that the number of parts should be larger than originally intended, this plate jig can easily be set up in a jig boring machine, the holes for guiding the drills can be rebored, and hardened steel bushings can be inserted. This would increase the life of this drill jig considerably. Plate jigs of the type shown by Fig. 1A are sometimes cyanide hardened to provide wear resistance in the drill holes.

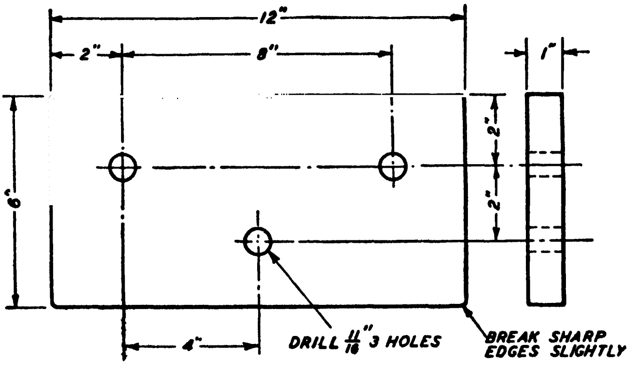
This same type of jig is sometimes designed for larger work, as shown by Fig. 2. This jig for large work is designed to be made of tank plate with elongated holes burned in it (by means of a torch) to reduce weight. It is provided with an eyebolt so that it can readily be lifted by means of a crane.

This plate jig was designed for the use of drill bushings and is made so that it can be clamped directly to the top of the piece part by means of **C**-clamps. This type of jig is used in a radial drill press and was designed for low-production quantities. If, on the other hand, large quantities of parts were to be produced, a jig



11/16" DRILL JIG
STEEL 1 REQ.

Fig. 1A. Working Drawing of a Plate Drill Jig



PIECE PART #105
C.R. ST. 50 REQ.

Fig. 1B. Production Drawing Showing a Drilled Plate

would be designed that would locate the entire work piece in definite relation to the holes to be drilled in the part.

An alternate design of plate jig is illustrated by Fig. 3. In this instance the plate jig is designed to be made from a gray iron casting with holes cored to provide lightness. This jig is designed to be placed over the work. One end is provided with adjustable stop screws and on the other is a screw with a hand knob for clamping the jig on the piece part. The designer therefore has a choice between plate steel and a gray iron casting in designing these jigs.

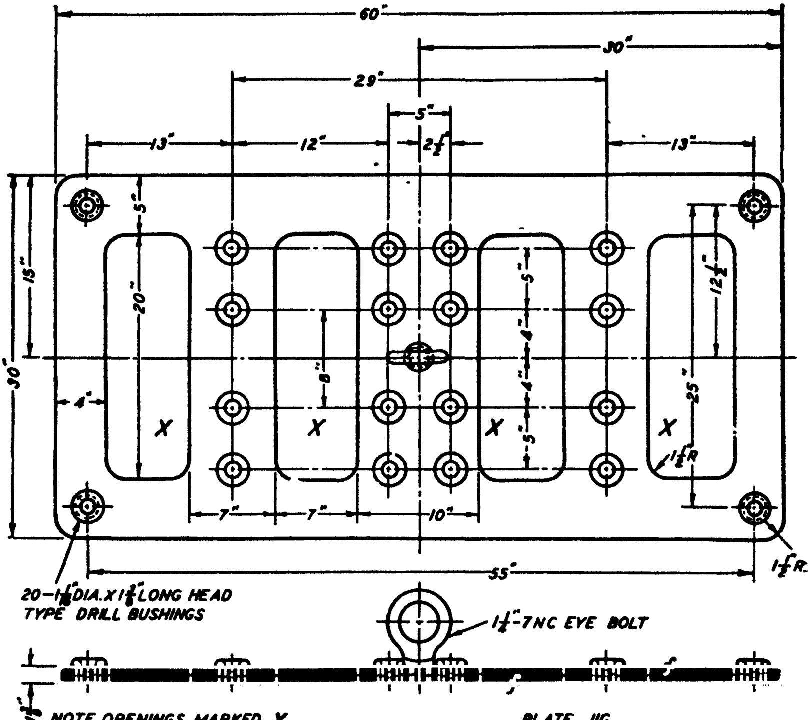

60"
30"
29"
5"
13"
12"
2½"
13"
15"
30"
20"
5"
4"
8"
5"
4"
4"
5"
12½"
25"
1½R
X
X
X
X
7"
7"
10"
55"
1½R.
20-1⅛" DIA. X 1⅛" LONG HEAD TYPE DRILL BUSHINGS
1¼"-7NC EYE BOLT
NOTE OPENINGS MARKED X ARE BURNED OUT.
PLATE JIG TANK PLATE ST. 1 REQ

Fig. 2. Low-Production Steel Plate Drill Jig

In using tank plate steel for a jig of this type, the outstanding advantage is that it is a stronger jig. Plate jigs made of steel are normalized to prevent warping and distortion. A disadvantage is that if the steel plate is dropped it will probably bend out of shape, which will cause considerable trouble unless this is detected; whereas with a cast-iron jig, if the casting has been properly normalized there is no distortion; that is, if dropped it will remain the same as

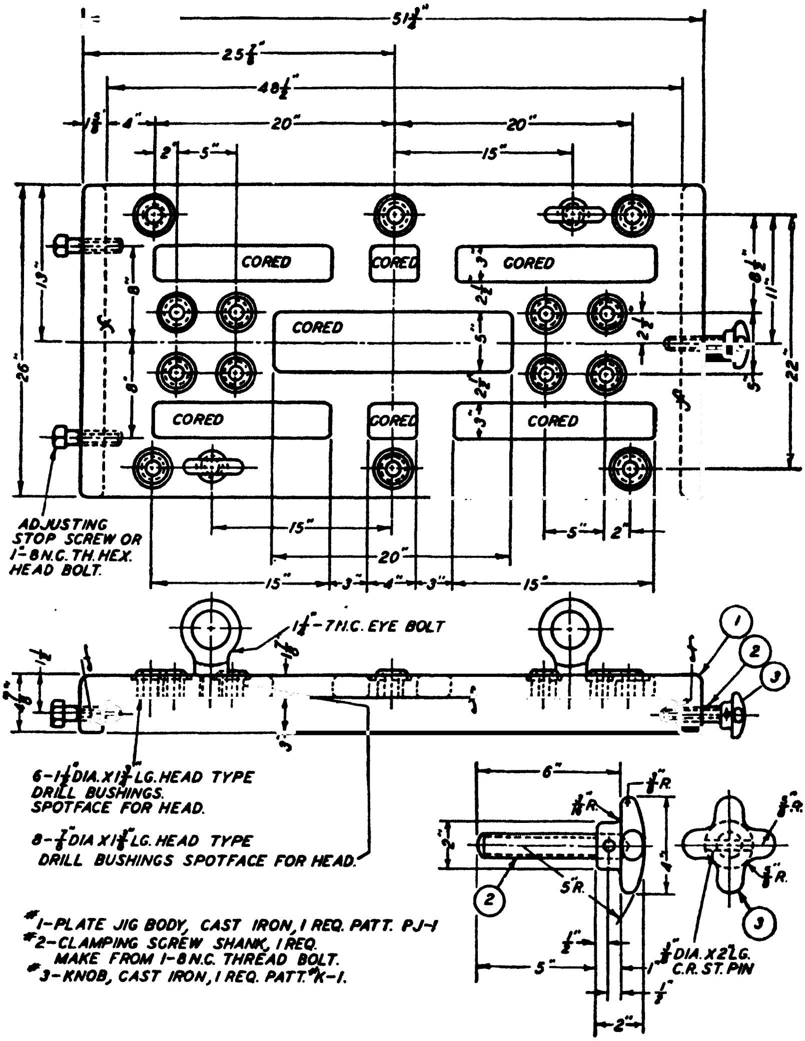

51¼"
25⅝"
48½"
1⅝"
4"
20"
20"
2"
5"
15"
CORED
CORED
CORED
CORED
CORED
CORED
CORED
13"
26"
8"
8"
8⅛"
11"
22"
2½"
5"
3"
15"
15"
20"
15"
3"
4"
3"
15"
5"
2"
ADJUSTING STOP SCREW OR 1"-8 N.C. TH. HEX. HEAD BOLT.
1¼"-7 N.C. EYE BOLT
1
2
3
6-1¼" DIA. X 1⅛" LG. HEAD TYPE DRILL BUSHINGS. SPOTFACE FOR HEAD.
8-¾" DIA X 1⅛" LG. HEAD TYPE DRILL BUSHINGS SPOTFACE FOR HEAD.
#1-PLATE JIG BODY, CAST IRON, 1 REQ. PATT. PJ-1
#2-CLAMPING SCREW SHANK, 1 REQ. MAKE FROM 1-8 N.C. THREAD BOLT.
#3-KNOB, CAST IRON, 1 REQ. PATT. #K-1.
6"
⅛"R.
⅛"R.
2"
4"
5"R.
⅛"R.
⅛"R.
¼"
5"
¼" DIA. X 2¼ LG. C.R. ST. PIN
¼"
2"

Fig. 3. Low-Production Cast-Iron Plate Drill Jig

before, unless possibly it should break. Therefore it will be seen that the type of material used in plate jigs is sometimes a matter of individual choice or preference.

For drilling a series of bolt holes in a flange of a piece part, plate jigs similar to Fig. 4 may be used. In this design of jig the

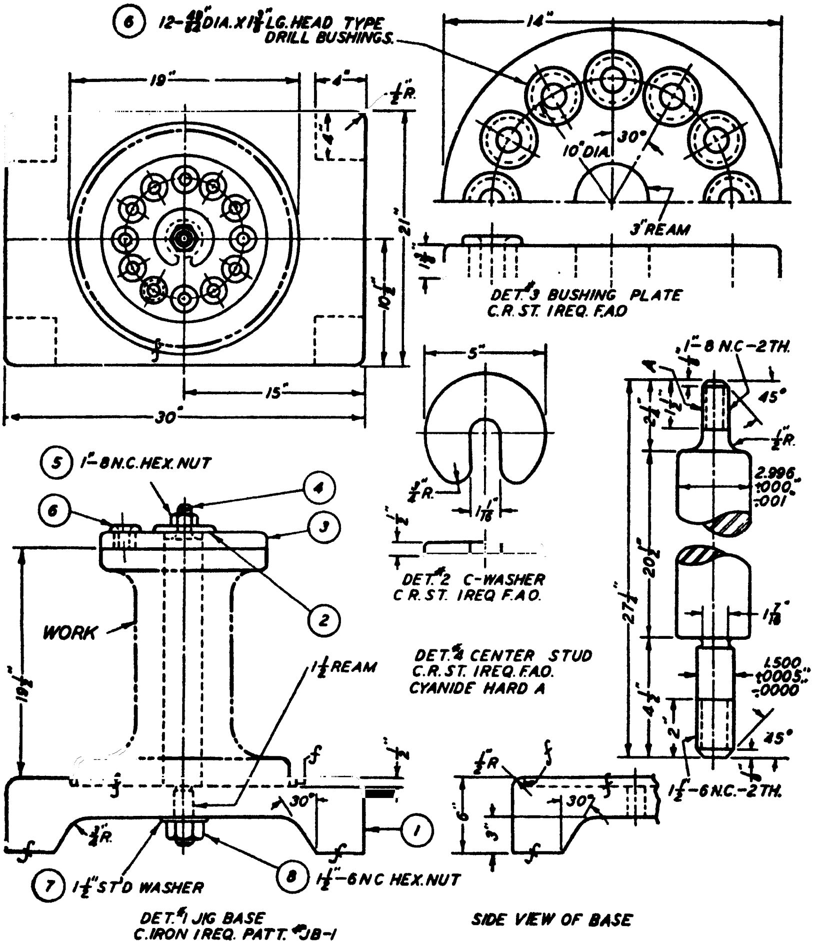


Fig. 4. Plate Drill Jig for Drilling Holes in a Flange

piece part has been previously machined on the flanges so that a jig can be designed which consists of a cast-iron base with a stud (*4*) mounted in it and a bushing plate (detail *3*) made out of cold-rolled steel with drill bushings inserted. The piece part is inserted over the stud and rests on the base. The bushing plate is designed so that the nut will clear the center hole. The **C**-washer (detail *2*) is then inserted on the stud between the bushing plate and the nut, and by means of a wrench the bushing plate is clamped solidly on the work. This type of jig is frequently used where piece parts are produced in low quantities. If a larger number of piece parts must be produced, a quick-acting jig would be designed for the job, as the design shown by Fig. 4 requires considerable time to load and unload the piece part.

ANGLE PLATE DRILL JIGS

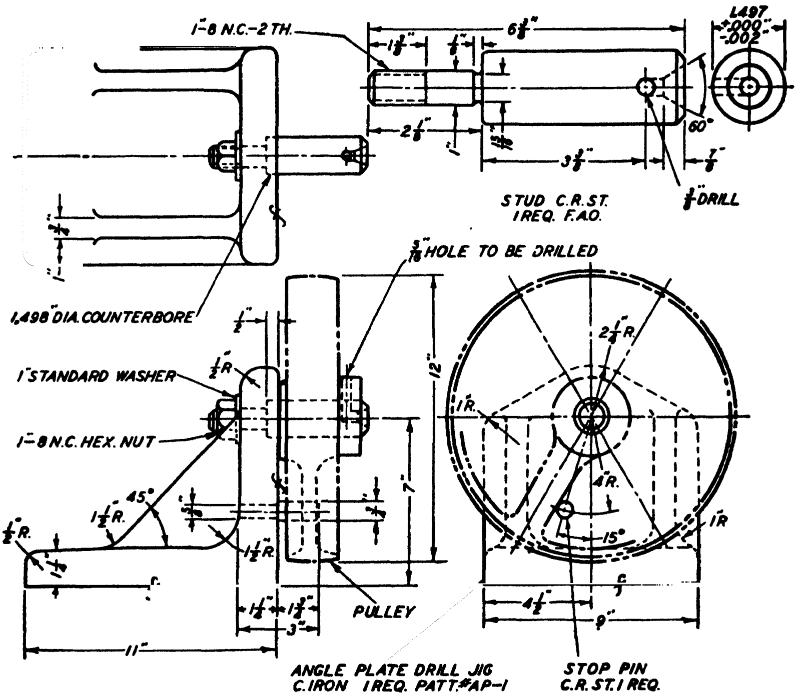


Fig. 5. Angle Plate Drill Jig for Drilling a Hole in a Pulley Hub

There are a number of piece parts that can be drilled in an angle plate drill jig. Fig. 5 shows such a jig for drilling a hole in a pulley hub. In this design no provisions have been made for drill bushings because the location of this hole is not important. The hole is drilled for tapping, so that a set screw can be inserted in the pulley hub to locate it on the shaft. This is a very simple form of jig, the base or angle plate is made of cast iron, and a stop pin is provided to locate the work centrally on one of the spokes of the pulley. Numerous adaptations of angle plate jigs can be designed as needed.

In many instances instead of making angle plate jigs of cast iron they are made of steel plate. Fig. 6 shows a welded construction, and the same conditions apply to an angle plate made of steel that were discussed in the preceding pages in regard to plate jigs. The advantage of an angle plate made in welded steel construction is that there is no waiting for castings and patterns, and plants equipped with welding facilities can easily make an angle plate without any delay.

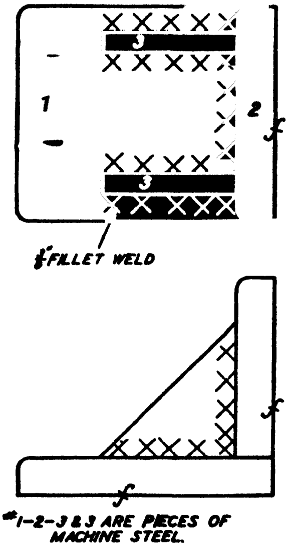


Fig. 6. Angle Plate Drill Jig; Base, Welded Construction

In many instances it is necessary to design angle plate jigs with a bushing plate to guide the drill so that it will drill a hole in a piece part in definite relation to other points or holes. Therefore a jig similar to Fig. 7 is designed. In this design, a cast-iron angle plate is used and the piece part is located by means of a central stud or locating pin, detail *3*. The part is located by means of stop pins (detail *4*) that have been inserted in one face of the angle plate. The bushing plate is a separate piece made out of cold-rolled steel, illustrated by detail *2* of Fig. 7.

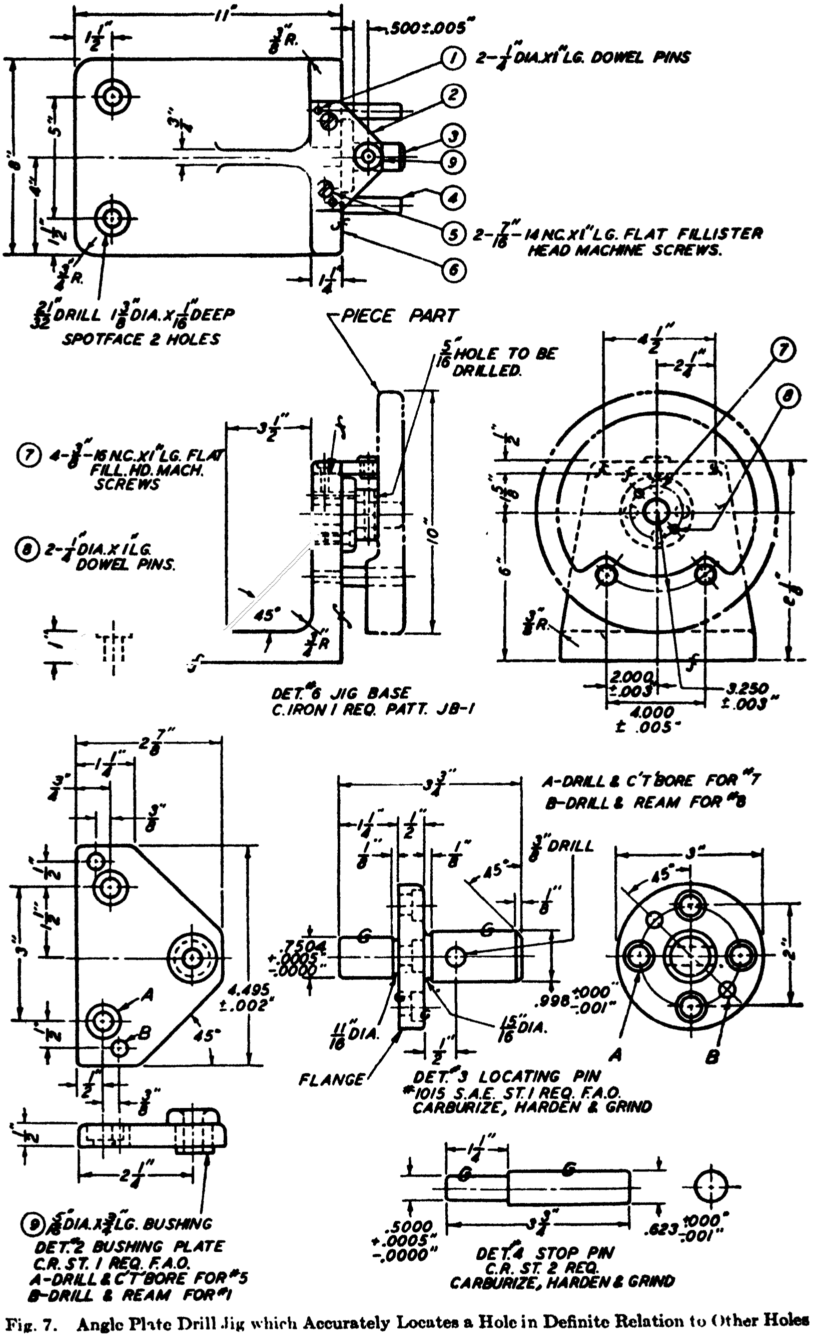


Fig. 7. Angle Plate Drill Jig which Accurately Locates a Hole in Definite Relation to Other Holes

Angle plates are also used for designing indexing jigs where it is necessary to drill holes on opposite sides of a work piece. The piece part is generally located in a body that is attached directly to the face of the angle plate, and stops are provided so that the piece part can be indexed 180°. This same type of jig can also be designed for drilling parts that would have angular holes in them.

LEAF DRILL JIGS

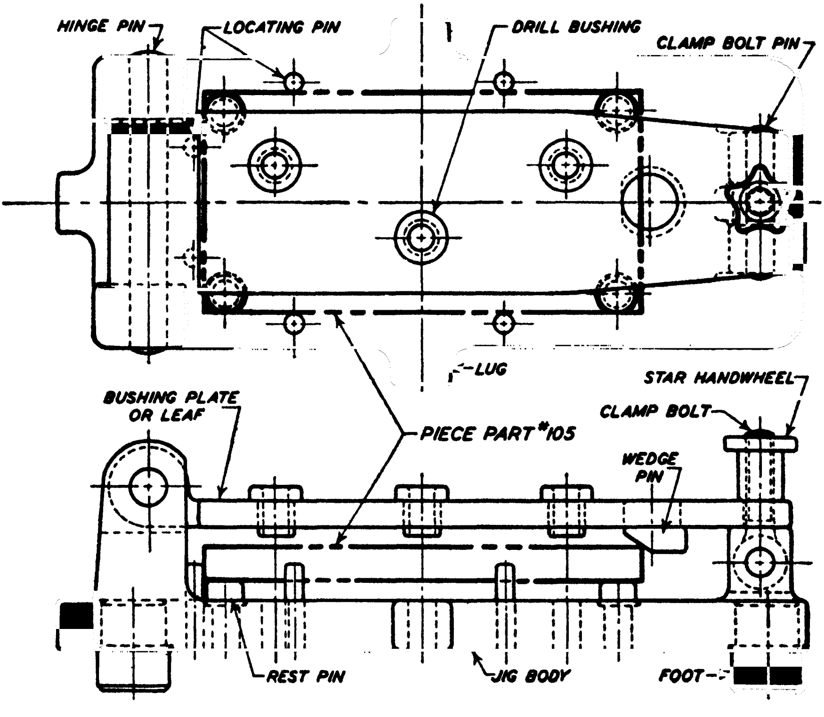


Fig. 8 Leaf Drill Jig for Drilling a Plate

In drilling pieces in one plane, for example a steel plate similar to the piece part previously described, a leaf drill jig, Fig. 8, is sometimes designed. This type of jig consists of a body, usually a gray iron casting, with hardened and ground jig feet inserted in the base of the body casting. You will note that lugs or ears have been provided in which to insert a pin to provide for a hinge for the leaf

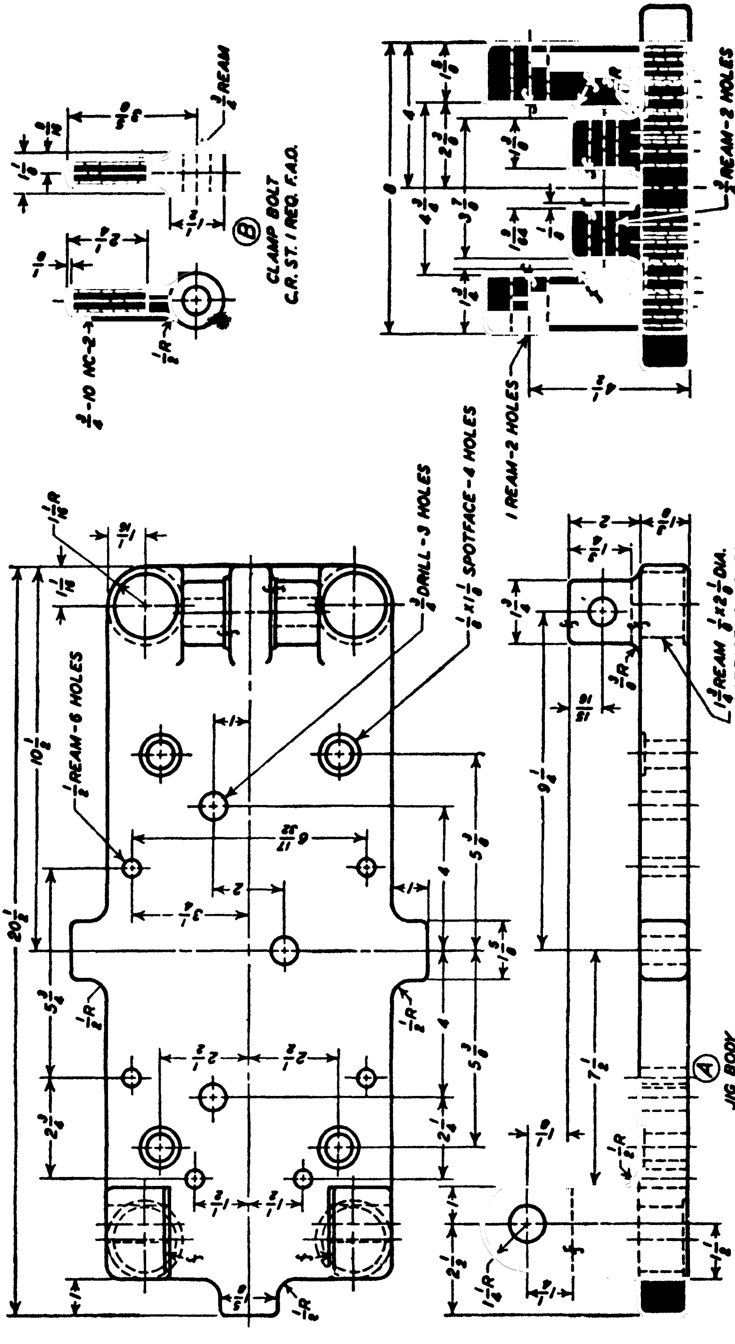


Fig. 9A. Working Drawing of Leaf Drill Jig Body and Clamp Bolt

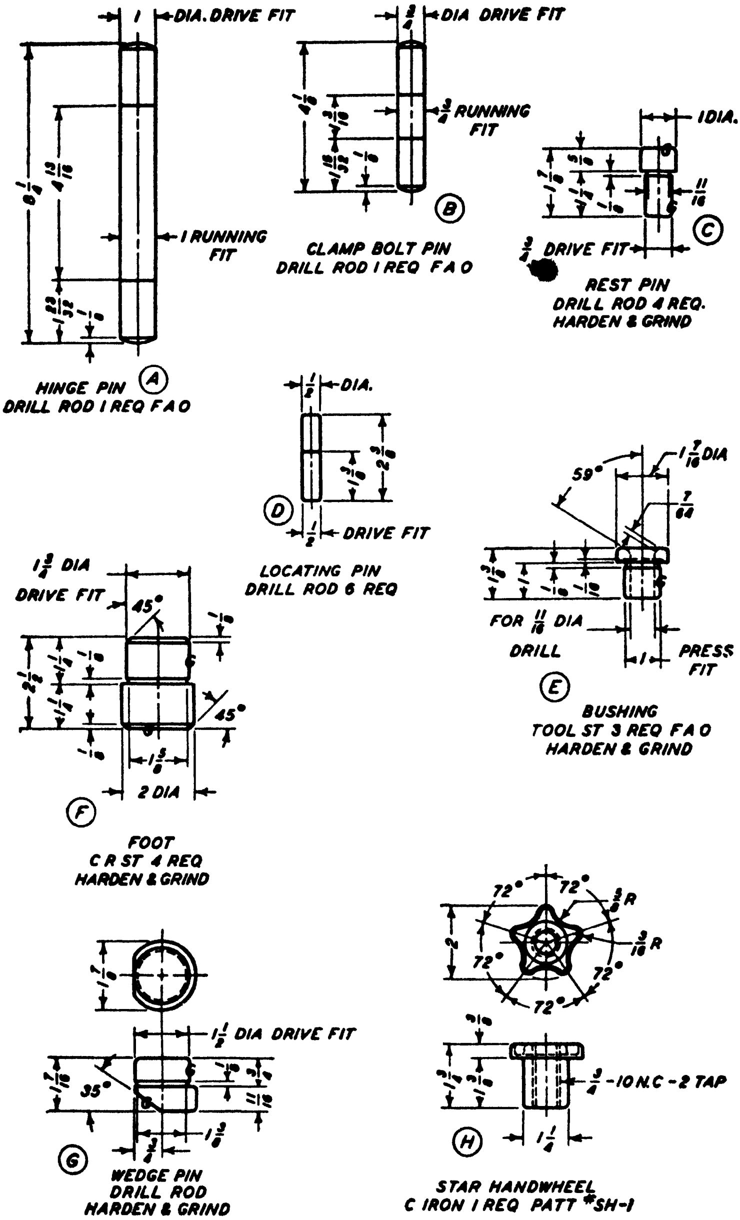
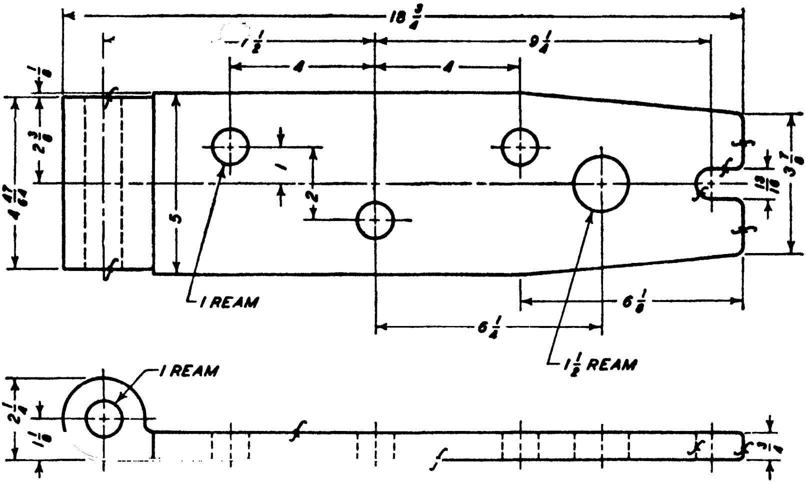


Fig. 9B. Working Drawing of Leaf Drill Jig Parts

or bushing plate. A clamp bolt is designed so that it can be pinned into the body of the jig, and a star handwheel is used to clamp the leaf of the jig so as to hold the work securely. Four hardened and ground rest pins on which to rest the piece part are inserted in the jig body, and a wedge pin is put into the leaf or bushing plate with a 45° angle for clamping the work up against the four locating pins in the rear and left portions of the jig.



BUSHING PLATE
MACH. ST. FORGING 1 REQ.

Fig. 10 Working Drawing of Bushing Plate for Leaf Drill Jig

Figs. 9A and 9B clearly illustrate the details of this type of design. In designing detail *A*, Fig. 9B, the designer could cheapen the cost of the jig by specifying that detail *A* be a 1″ diameter drive fit the entire length instead of having two diameters. This could be done by specifying a 1.002″ reamed hole in the bushing plate to permit it to move freely on the hinge pin.

Fig. 10 illustrates the design of a leaf or bushing plate. This can be made of a steel forging or of cast iron if desired. Steel would be more desirable for an item of this kind, but a steel forging is somewhat more expensive than cast iron, although it is much stronger. A compromise could be effected on this design by welding a piece of round shafting on the end of this ¾″ steel plate for the hinge section of the leaf or bushing plate.

SHAFT DRILL JIGS

To drill holes in round shafts a simple form of drill jig is generally used where production requirements are low. Fig. 11 is a design of a short-shaft drill jig. This design is a built-up jig which consists of a solid block with a 7/8″ hole bored through it to hold the shaft. A drill bushing is inserted in the top portion of the jig, a stop is provided at the rear so that the shaft will be in definite location. A cap screw has an ordinary hexagon-head bolt with a hole drilled through the hexagon head, as shown, for the insertion of a pin. This provides additional leverage for the operator to clamp the shaft in the jig. The 60° countersink on the right end allows easy insertion of the work. This is an inexpensive jig to design and make, and for low-production it serves the purpose very well.

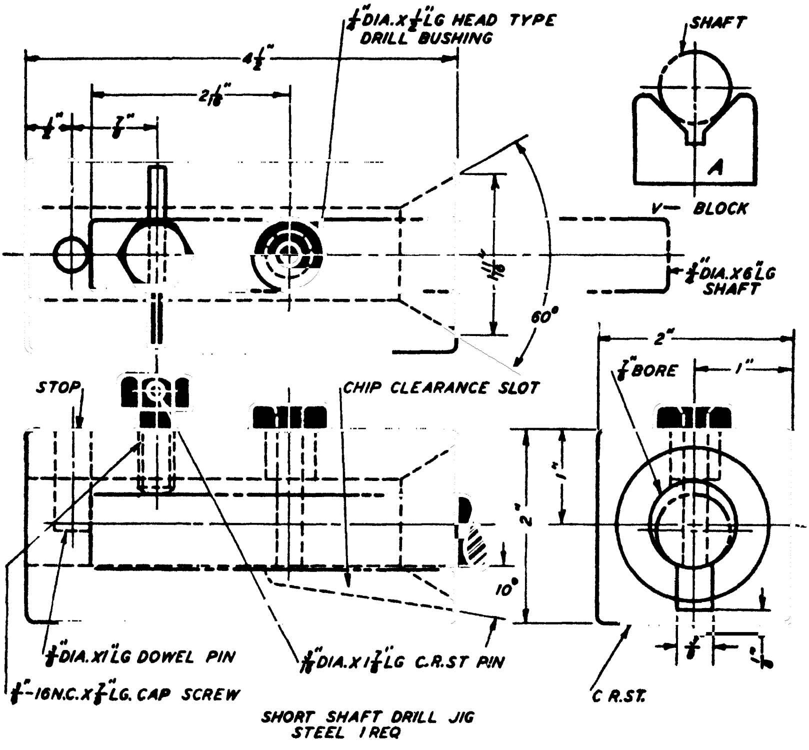


Fig. 11. Short Shaft Drill Jig

Where piece parts must be produced in fairly large quantities, particularly for parts similar to Fig. 12, a different type of drill jig is designed. Fig. 13 illustrates a shaft drilling jig for use where the loading and unloading must be as fast as possible and where the drilled hole must be definitely located in relation to other dimensions. The drill jig illustrated by Fig. 13 has a base that is built up by welded construction. The two **V**-blocks are welded to the jig base at either end and are provided with hardened and ground rest pins (*12*). These are set at 45° angles on each side of the center line, making a total of 90° between the rest pins. In the center of the jig an additional piece is welded for the insertion of a commercial clamping mechanism (*8*). The bushing plate (*7*) is mounted by means of screws (*2*) and dowel pins (*1*), with a drill bushing (*6*) located in the proper place on it. The shaft is inserted in the jig, and a hardened and ground stop or gage plate (*3*) is provided for definitely locating the shaft at the correct distance from the end.

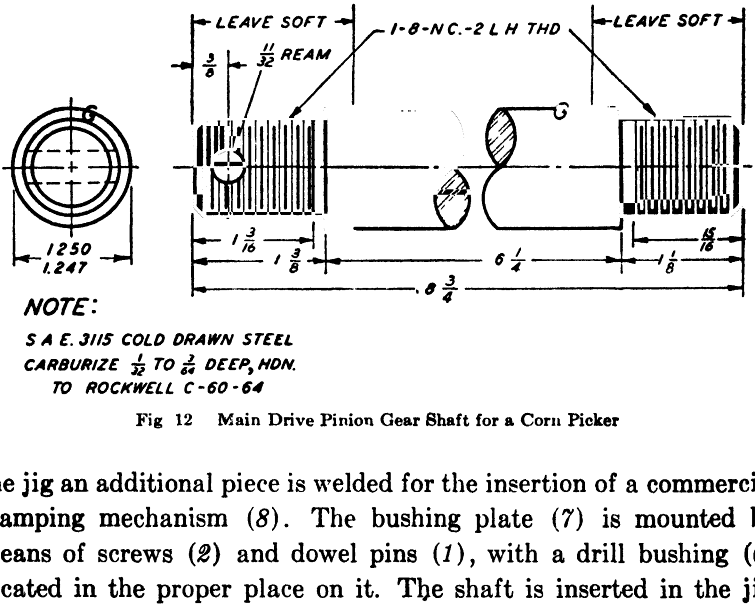
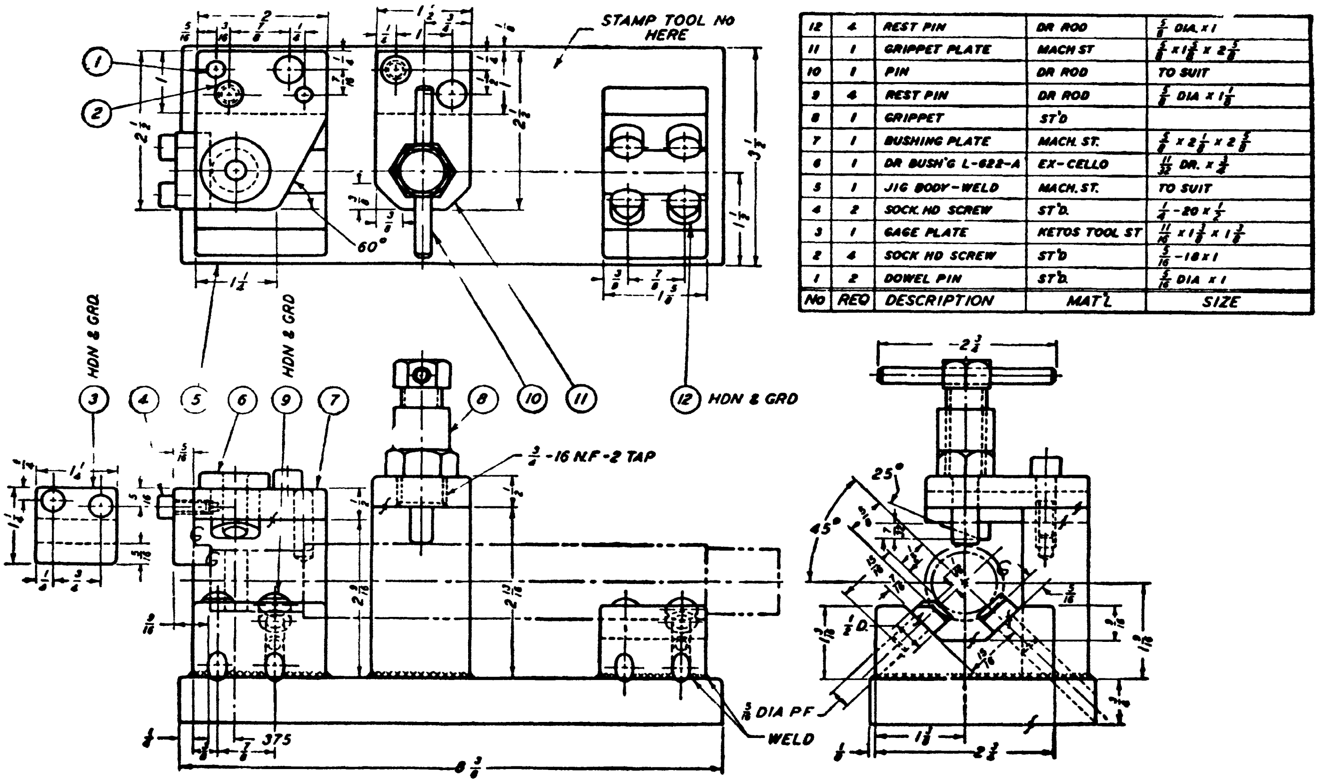


Fig 12 Main Drive Pinion Gear Shaft for a Corn Picker

Fig. 14 illustrates the clamping mechanism, which can be purchased in various sizes to suit the needs of the individual job. This provides a quick method of clamping a shaft in a drill jig.

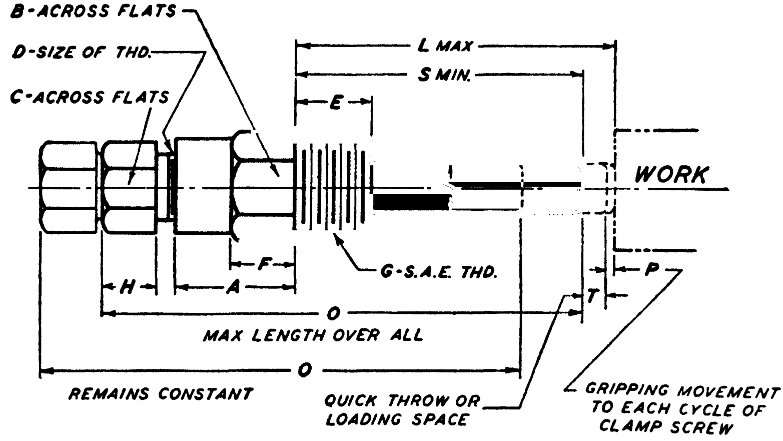
For drilling long shafts where two or more holes must be drilled in the shaft in definite relation to other dimensions, a drill jig similar to Fig. 15 is usually designed. This jig, as you will note, is made with a base (*1*) having uprights (*9* and *12*) welded on its ends **V**-blocks (details *7* and *8*) are held in place by screws and dowels.



NO	REQ	DESCRIPTION	MAT'L	SIZE
12	4	REST PIN	DR ROD	$\frac{5}{8}$ DIA. x 1
11	1	GRIPPET PLATE	MACH ST	$\frac{5}{8} \times 1\frac{5}{8} \times 2\frac{5}{8}$
10	1	PIN	DR ROD	TO SUIT
9	4	REST PIN	DR ROD	$\frac{5}{8}$ DIA x $1\frac{1}{8}$
8	1	GRIPPET	ST'D	
7	1	BUSHING PLATE	MACH. ST.	$\frac{5}{8} \times 2\frac{1}{8} \times 2\frac{5}{8}$
6	1	DR BUSH'G L-622-A	EX-CELLO	$\frac{11}{32}$ DR. x $\frac{3}{4}$
5	1	JIG BODY-WELD	MACH. ST.	TO SUIT
4	2	SOCK. HD SCREW	ST'D.	$\frac{1}{4}$-20 x $\frac{1}{2}$
3	1	GAGE PLATE	KETOS TOOL ST	$\frac{11}{16} \times 1\frac{3}{8} \times 1\frac{3}{8}$
2	4	SOCK HD SCREW	ST'D	$\frac{5}{16}$-18 x 1
1	2	DOWEL PIN	ST'D.	$\frac{5}{16}$ DIA x 1

Fig. 13. Drill Jig for Drilling a Hole in the Pinion Gear Shaft Shown in Fig. 12

Grippet Specifications



Size	S	L	A	B	C	D	E	F	G	H	J	O	P	T
G-12	27/32	1 1/4	1	5/8	1/2	1/2-13	7/16	3/8	5/8-18	3/8	.278	2 7/8	.058	1/8
G-58	1	1 1/2	1 1/8	3/4	5/8	5/8-11	1/2	7/16	3/4-16	7/16	.387	3 7/32	.068	5/32
G-34	1 1/16	1 5/8	1 1/4	7/8	3/4	3/4-10	9/16	1/2	7/8-14	1/2	.528	3 9/16	.075	3/16
G-100	1 7/8	2 3/4	1 7/8	1 3/8	1	1-8	7/8	3/4	1 1/8-12	3/4	.620	5 5/8	.094	1/4

Fig. 14. Clamping Mechanism
Courtesy of Wedge-Lock Tool Co., Chicago, Illinois

On upright *9* is a bushing plate (*10*) with two drill bushings (*4*) inserted; a stop (*15*) is provided to accurately locate the shaft. On upright *12* is a bushing plate (*11*) with one bushing (*4*). Two clamp screws (*13*) are used to clamp the work firmly in the jig. This jig is very inexpensive to design and build and is commonly used. However, if large numbers of shafts were to be drilled, patented drill jigs would be incorporated in the design. For example, a steel base would be provided, two or more quick-clamping drill jigs would be located in the correct positions, and the work would be clamped in the jig by means of quick-acting levers.

The designs of shaft drilling jigs previously described have been for drilling holes at right angles to the axis of the shaft. In many cases it is necessary to drill a hole in the end of a shaft, such as certain types of gear shafts. Fig. 16 illustrates a design of a jig for drilling a 7/32" hole in the end of an idler gear shaft. In this design it will be noted that a base (*1*) with a welded upright (*2*)

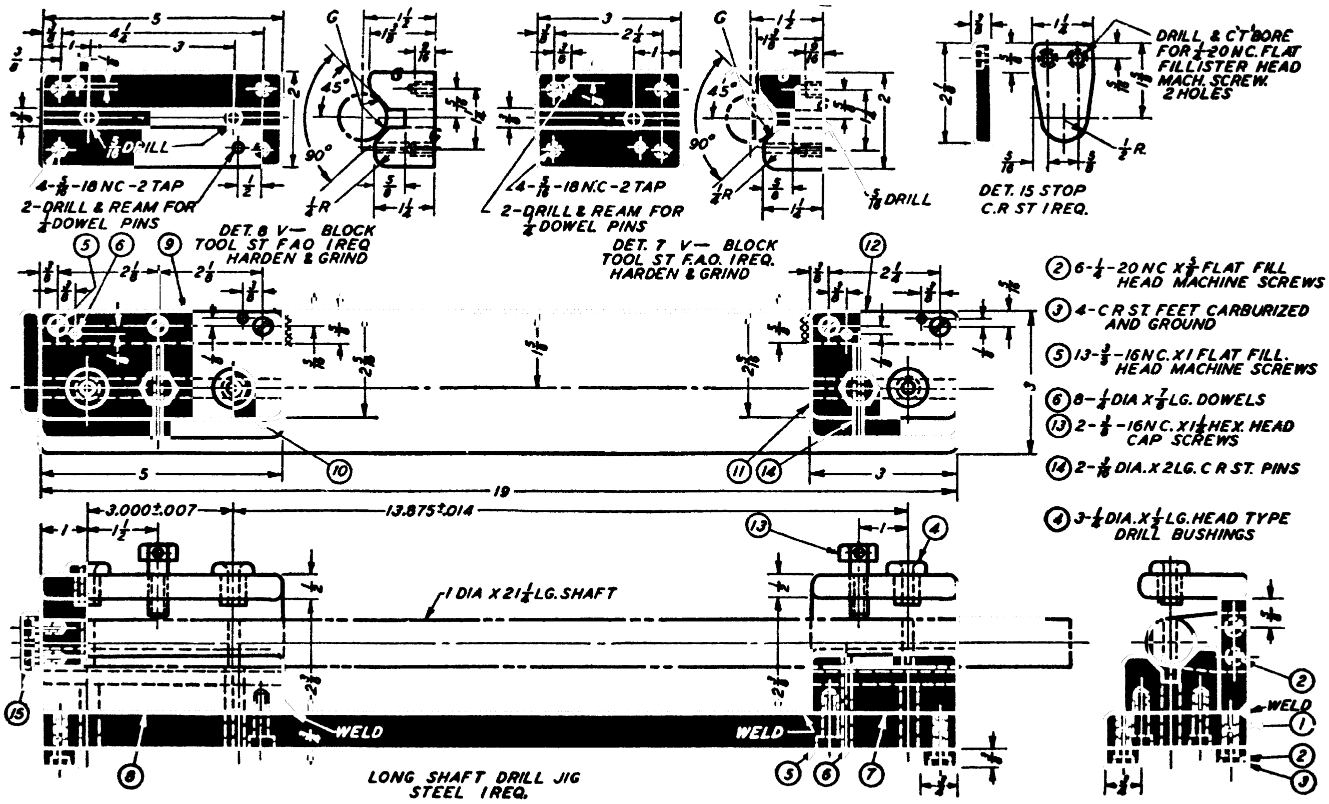
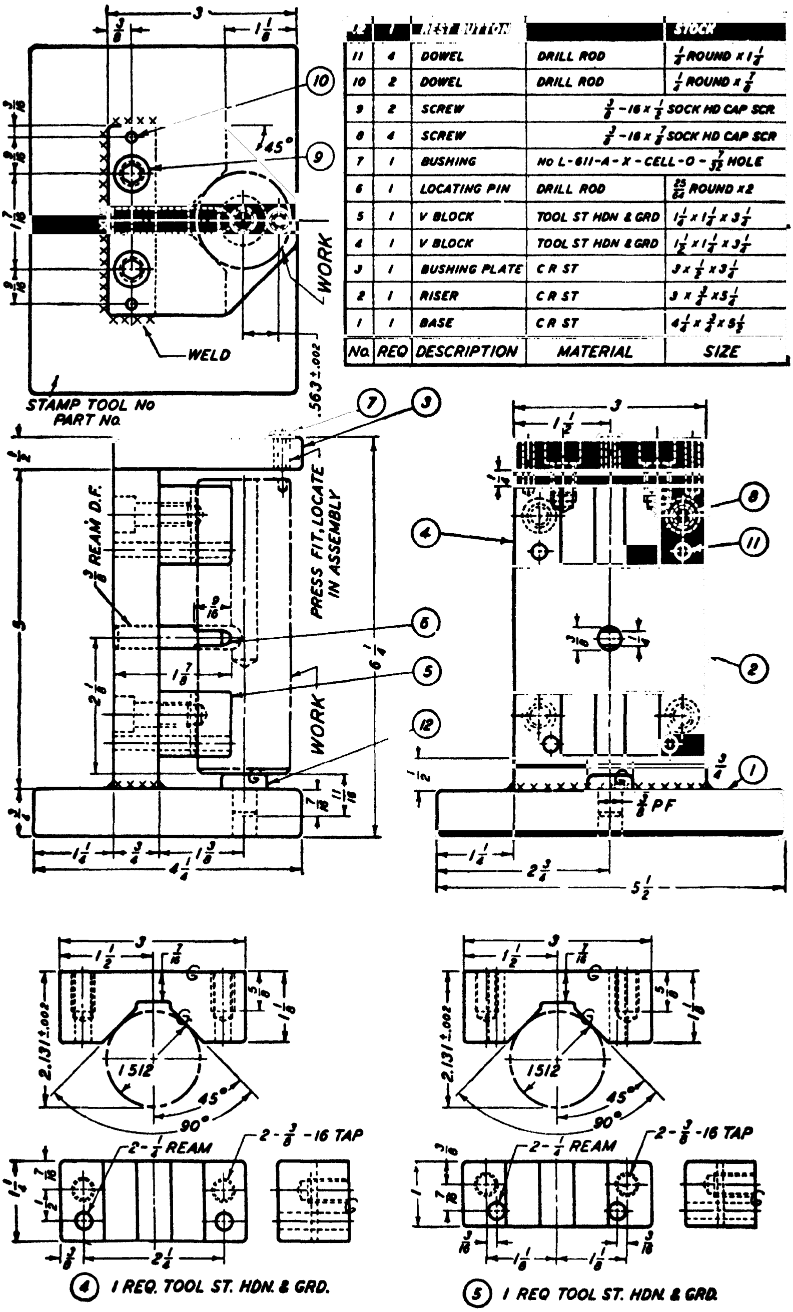

DET. 8 V— BLOCK
TOOL ST F.A.O. 1 REQ
HARDEN & GRIND
4-5/16-18 NC-2 TAP
2-DRILL & REAM FOR 1/4 DOWEL PINS
5/16 DRILL
G
45°
90°
1/2 R
DET. 7 V— BLOCK
TOOL ST F.A.O. 1 REQ.
HARDEN & GRIND
DRILL & C'T'BORE FOR 1/4-20 N.C. FLAT FILLISTER HEAD MACH. SCREW. 2 HOLES
DET. 15 STOP
C.R ST 1 REQ.
② 6-1/4-20 NC x 5/8 FLAT FILL HEAD MACHINE SCREWS
③ 4-C R ST. FEET CARBURIZED AND GROUND
⑤ 13-3/8-16 N.C. x 1 FLAT FILL. HEAD MACHINE SCREWS
⑥ 8-1/4 DIA x 7/8 LG. DOWELS
⑬ 2-3/8-16 N.C. x 1 1/4 HEX. HEAD CAP SCREWS
⑭ 2-3/8 DIA. x 2 LG. C R ST. PINS
④ 3-1/2 DIA. x 1/2 LG. HEAD TYPE DRILL BUSHINGS
3.000±.007
13.875±.014
19
1 DIA x 21 1/4 LG. SHAFT
WELD
LONG SHAFT DRILL JIG
STEEL 1 REQ.
① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨ ⑩ ⑪ ⑫ ⑬ ⑭ ⑮

Fig. 15. Long Shaft Drill Jig for Definitely Locating Center Distances of Holes



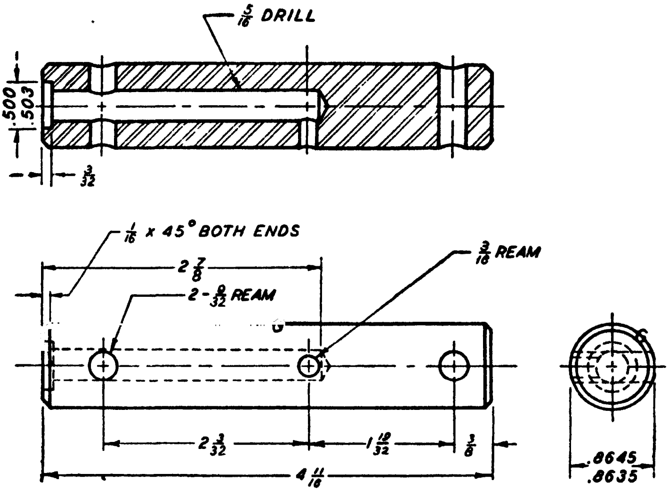
No.	REQ	DESCRIPTION	MATERIAL	SIZE
12	1	REST BUTTON		STOCK
11	4	DOWEL	DRILL ROD	1/4 ROUND x 1 1/4
10	2	DOWEL	DRILL ROD	1/4 ROUND x 7/8
9	2	SCREW	3/8 – 16 x 1/2 SOCK HD CAP SCR	
8	4	SCREW	3/8 – 16 x 7/8 SOCK HD CAP SCR	
7	1	BUSHING	No L-611-A-X-CELL-O-7/32 HOLE	
6	1	LOCATING PIN	DRILL ROD	25/64 ROUND x 2
5	1	V BLOCK	TOOL ST HDN & GRD	1 1/4 x 1 1/4 x 3 1/4
4	1	V BLOCK	TOOL ST HDN & GRD	1 1/2 x 1 1/4 x 3 1/4
3	1	BUSHING PLATE	C R ST	3 x 1/2 x 3 1/4
2	1	RISER	C R ST	3 x 3/4 x 5 1/4
1	1	BASE	C R ST	4 1/4 x 3/4 x 5 1/2

④ 1 REQ. TOOL ST. HDN. & GRD.

⑤ 1 REQ TOOL ST. HDN. & GRD.

Fig. 13. Drill Jig for Drilling Hole in Reverse Idler Shaft

has been designed, and on this upright two **V**-blocks (*4* and *5*) have been mounted by means of screws (*8*) and dowel pins (*11*). In addition, a bushing plate (*3*) is provided on the top of the upright member, and the drill bushing (*7*) is located in the proper position. The $\frac{7}{32}''$ hole to be drilled in this piece part does not require any definite location other than the center distance, or .563″. No clamp is provided for holding the piece part in the jig. This job is done in a sensitive drill press and the shaft is held in the jig by the operator while the hole is drilled.



S.A.E. 1015 ST.
CARBURIZE $\frac{3}{64}$ TO $\frac{1}{16}$ DEEP
SCLEROSCOPE 70-95 HARD

Fig. 17. Reverse Idler Shaft

Where it is desirable to drill shafts in large quantities, for example a piece part such as that shown in Fig. 17, a design of jig similar to that shown in Figs. 18A and 18B is usually made. You will note that this jig consists of a steel base (*16*) with a welded upright on which is mounted a bushing plate. Stops or gage pins (*3*) are provided at either end of the bushing plate (*4*) for accurately locating the shaft in the drill jig. The left-hand gage pin has been chamfered off to provide for easy loading. The part is located by means of a 90° vee in the bushing plate. This vee is obtained by means of hardened and ground pins that are inserted in the bushing

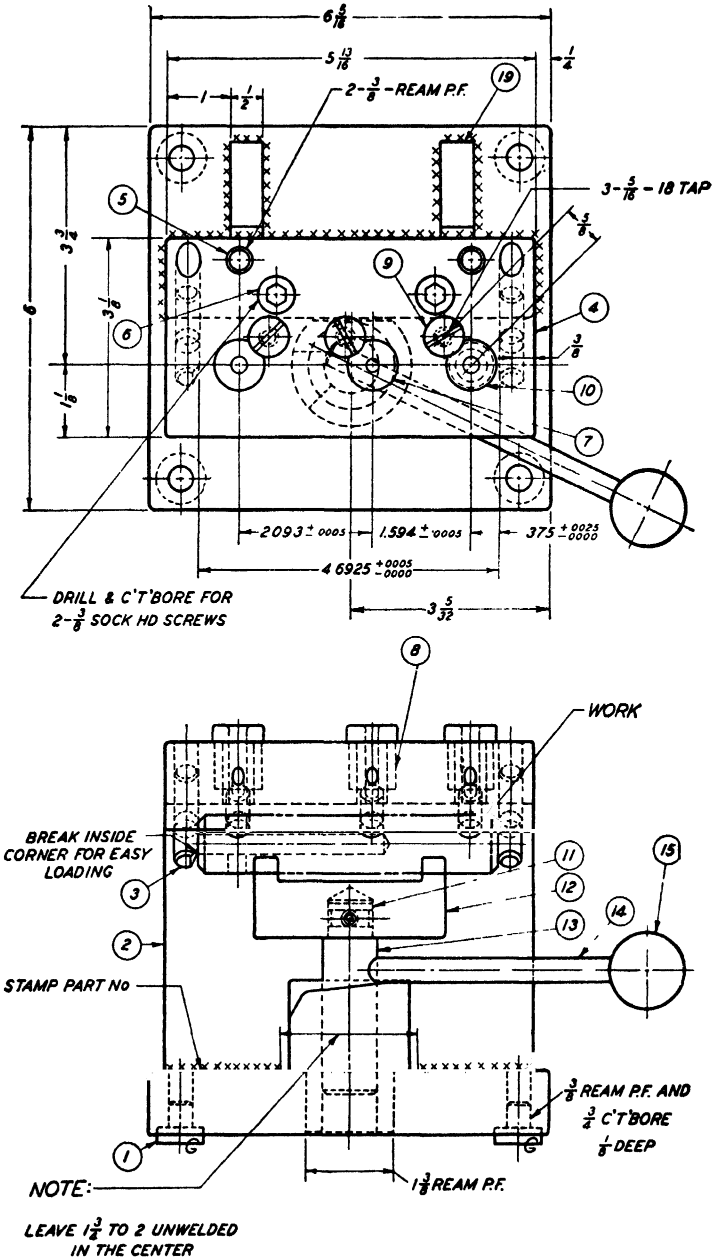


Fig. 18A. Design of Drill Jig for Drilling Three Holes in Reverse Idler Shaft

No.	REQ.	DESCRIPTION	MATERIAL	SIZE
19	2	RIB	C.R. ST.	$\frac{1}{2} \times 1\frac{1}{2} \times 3\frac{1}{2}$
18	6	REST PIN	DR. ROD	$\frac{3}{8}$ DIA. × $\frac{1}{2}$
17	1	CAM	#11 RED STAR ST.	2 DIA. × $2\frac{1}{2}$
16	1	BASE	C.R. ST.	$1 \times 6 \times 6\frac{1}{16}$
15	1	BALL	C.D. ST.	$1\frac{1}{4}$ DIA.
14	1	HANDLE	C.D. ST.	$\frac{3}{8}$ DIA. × $6\frac{1}{2}$
13	1	SHAFT	#11 RED STAR ST.	1 DIA. × $3\frac{1}{8}$
12	1	V-CLAMP	S.A.E. #1045	$1\frac{1}{8} \times 1\frac{1}{2} \times 3\frac{1}{8}$
11	1	SOCK. SET SCR. HALF DOG POINT		$\frac{1}{4}$-20 × $\frac{7}{16}$
10	2	BUSHING	XLO	1 S 12 FOR $\frac{3}{8}$ REAMER
9	3	LOCK SCREW	XLO	#1
8	3	LINER	XLO	0-422
7	1	BUSHING	XLO	1 S 12 FOR $\frac{3}{16}$ DRILL
6	2	SOCK. HD. SCR.		$\frac{3}{8}$-16 × $1\frac{1}{2}$
5	2	DOWEL		$\frac{3}{8}$ DIA. × $1\frac{1}{2}$
4	1	BUSHING PLATE	MACH. ST.	$1\frac{1}{2} \times 3\frac{1}{2} \times 6$
3	2	GAGE PIN	DR. ROD	$\frac{3}{8}$ DIA. × 2
2	1	PLATE	C.R. ST.	$1\frac{1}{4} \times 3\frac{7}{8} \times 6$
1	4	JIG FOOT	ST'D.	S-29-8375

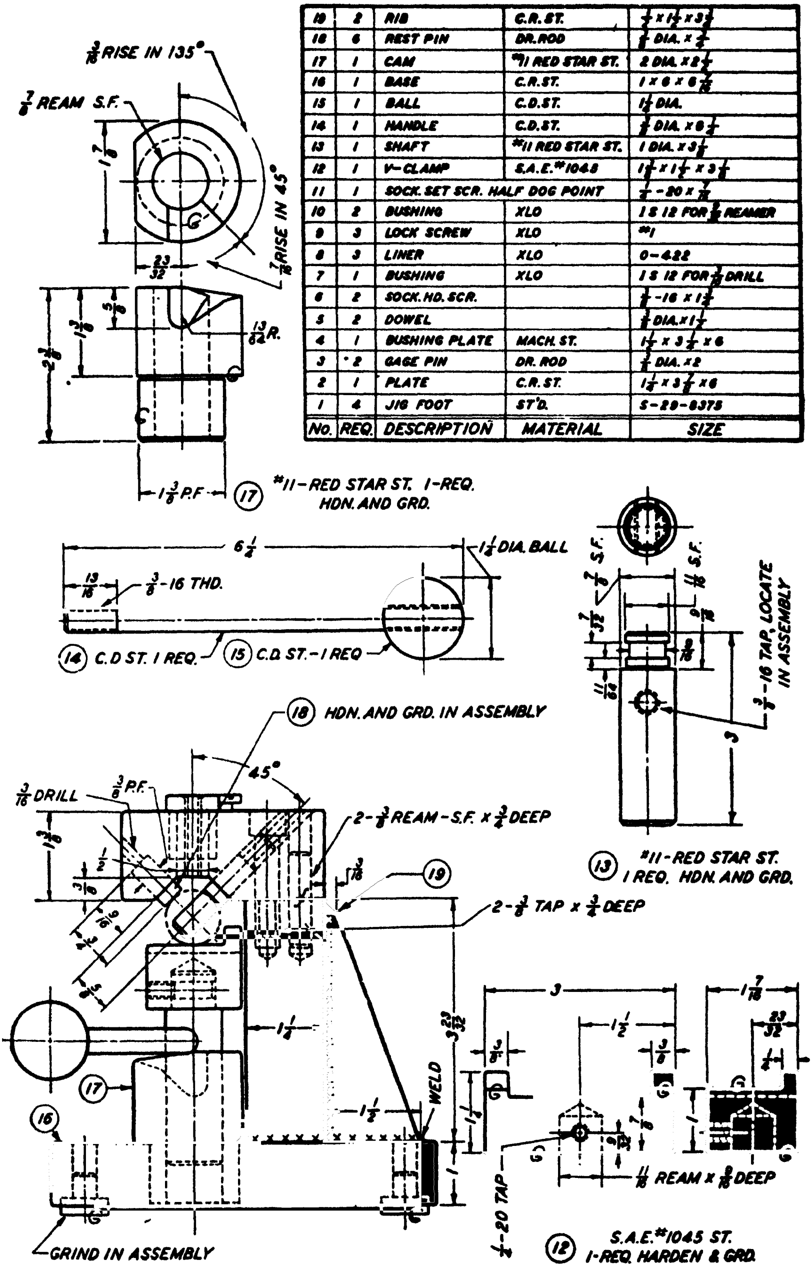


Fig. 18B. Details and Bill of Materials for the Design Shown in Fig. 18A

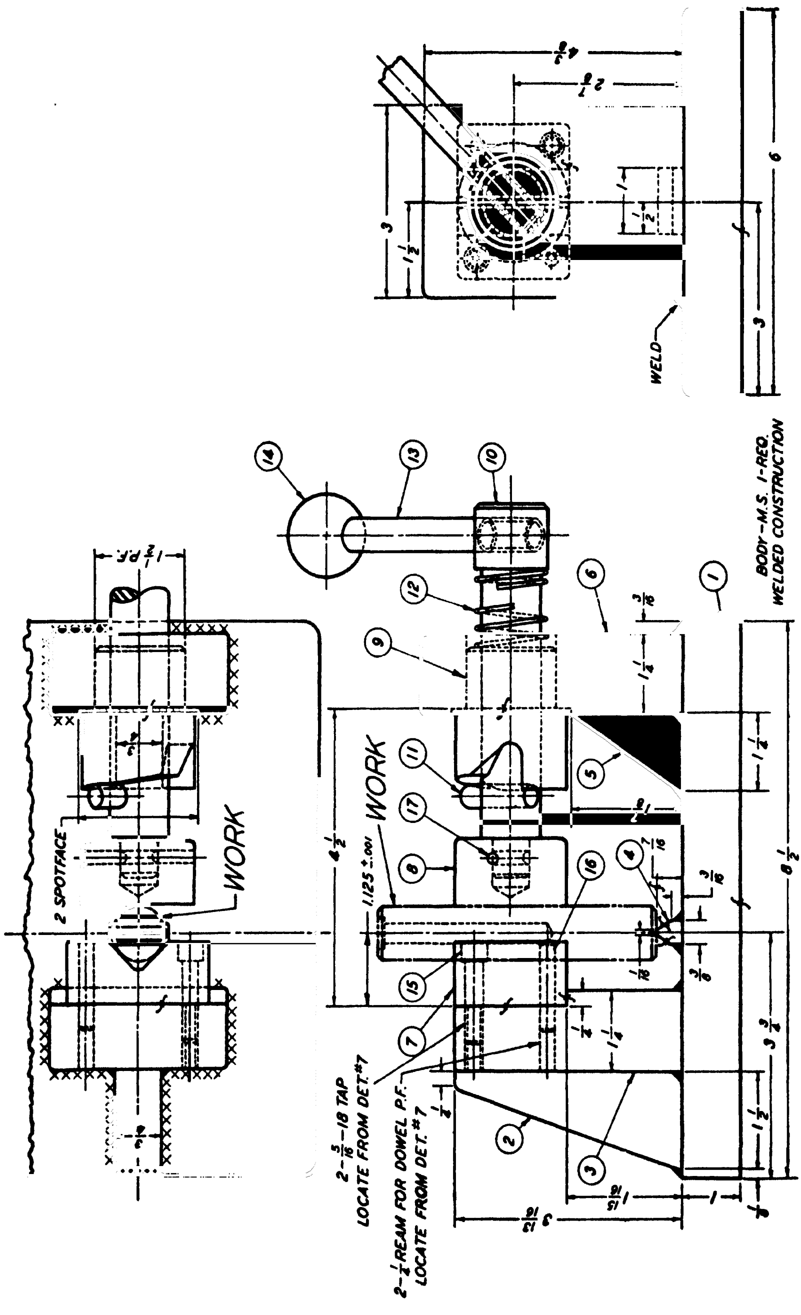
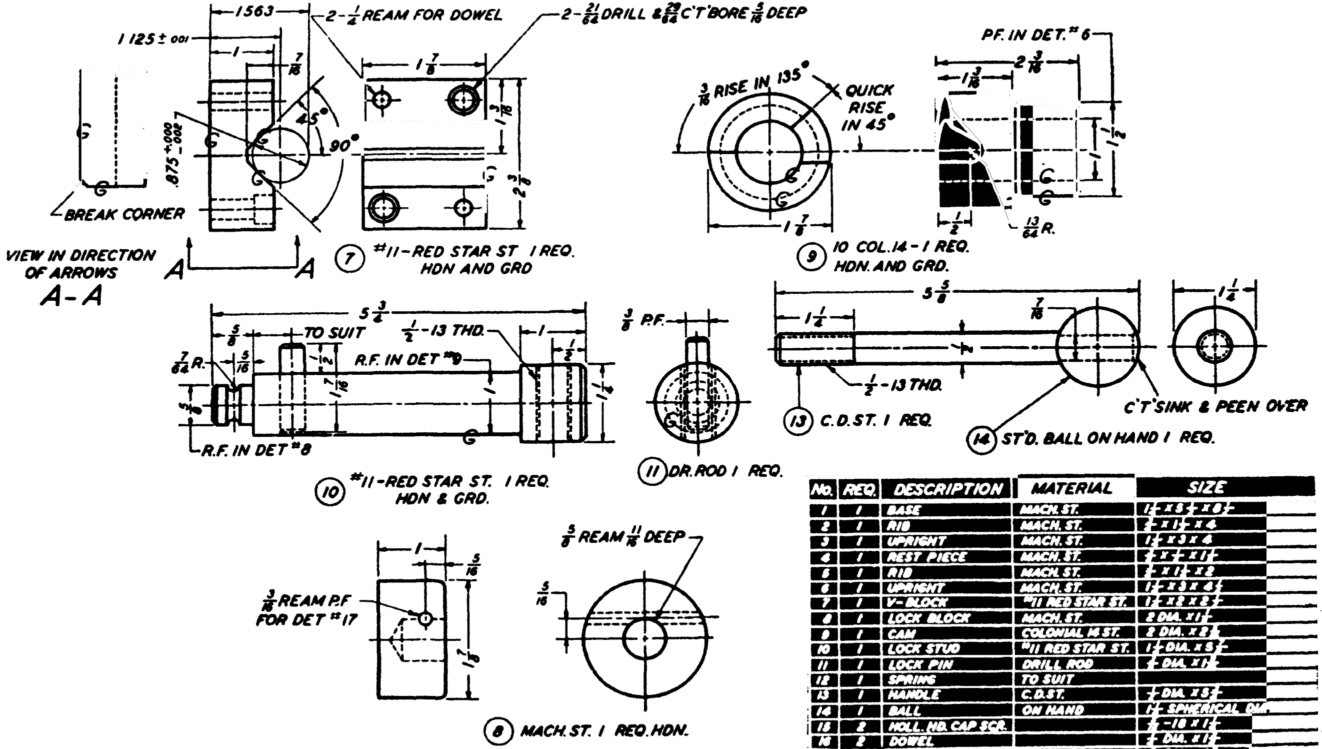


Fig. 19A. Drill Jig for Drilling 5/16" Hole in Reverse Idler Shaft



No.	REQ.	DESCRIPTION	MATERIAL	SIZE
1	1	BASE	MACH. ST.	1[illegible] x 5[illegible] x 8[illegible]
2	1	RIB	MACH. ST.	[illegible] x 1[illegible] x 4
3	1	UPRIGHT	MACH. ST.	1[illegible] x 3 x 4
4	1	REST PIECE	MACH. ST.	[illegible] x [illegible] x 1[illegible]
5	1	RIB	MACH. ST.	[illegible] x 1[illegible] x 2
6	1	UPRIGHT	MACH. ST.	1[illegible] x 3 x 4[illegible]
7	1	V-BLOCK	#11 RED STAR ST.	1[illegible] x 2 x 2[illegible]
8	1	LOCK BLOCK	MACH. ST.	2 DIA. x 1[illegible]
9	1	CAM	COLONIAL 14 ST.	2 DIA. x 2[illegible]
10	1	LOCK STUD	#11 RED STAR ST.	1[illegible] DIA. x 5[illegible]
11	1	LOCK PIN	DRILL ROD	[illegible] DIA. x 1[illegible]
12	1	SPRING	TO SUIT	
13	1	HANDLE	C.D.ST.	[illegible] DIA. x 5[illegible]
14	1	BALL	ON HAND	1[illegible] SPHERICAL DIA.
15	2	HOLL. HD. CAP SCR.		[illegible]-18 x 1[illegible]
16	2	DOWEL		[illegible] DIA. x 1[illegible]
17	1	PIN	DRILL ROD	[illegible] DIA. x 1[illegible]

Fig. 19B. Details and Bill of Materials for the Design Shown in Fig. 19A

plate. You will note that knockout holes have been provided so that these hardened and ground rest pins can be removed in the event they become worn through use. The part is clamped in position by means of a vertical cam (*17*) which has been designed so that the piece part is inserted in the locator and then the cam is actuated so as to clamp the piece of the shaft directly against the 90° vee. This jig allows fast operation and the pieces can be loaded and unloaded very rapidly.

Referring to Fig. 17, the piece part, you will note that a 5/16" hole is drilled parallel to the axis of the shaft. Figs. 19A and 19B illustrate the design of jig employed for drilling this hole. This piece part has been machined in an automatic screw machine and a center was left on the end of the shaft; therefore in this design of jig no bushing plate has been provided, as the center left in the shaft will act as a guide for the 5/16" drill. You will note in this cam clamping arrangement that a spring (*12*) has been inserted in the back of the cam to insure a quick return. This is necessary when using a cam of this design in a horizontal position as it provides for a quick return when the cam is released.

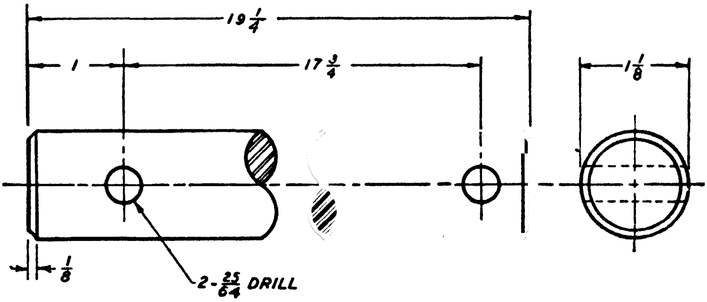


Fig. 20. Main Drive Sprocket Shaft

For drilling holes in both ends of a shaft where the distance between centers is long, as in Fig. 20, a jig similar to that shown in Figs. 21A and 21B is designed. This consists of a base (*10*) with three V-blocks welded to it, one in the center and one on each end. Each end V-block has a bushing plate mounted on it by means of screws (*5*) and dowel pins (*6*), and a clamp screw (*8*) is mounted on the center section. Each V-block has four hardened and ground rest pins inserted on the angular portion. The holes for rest pins

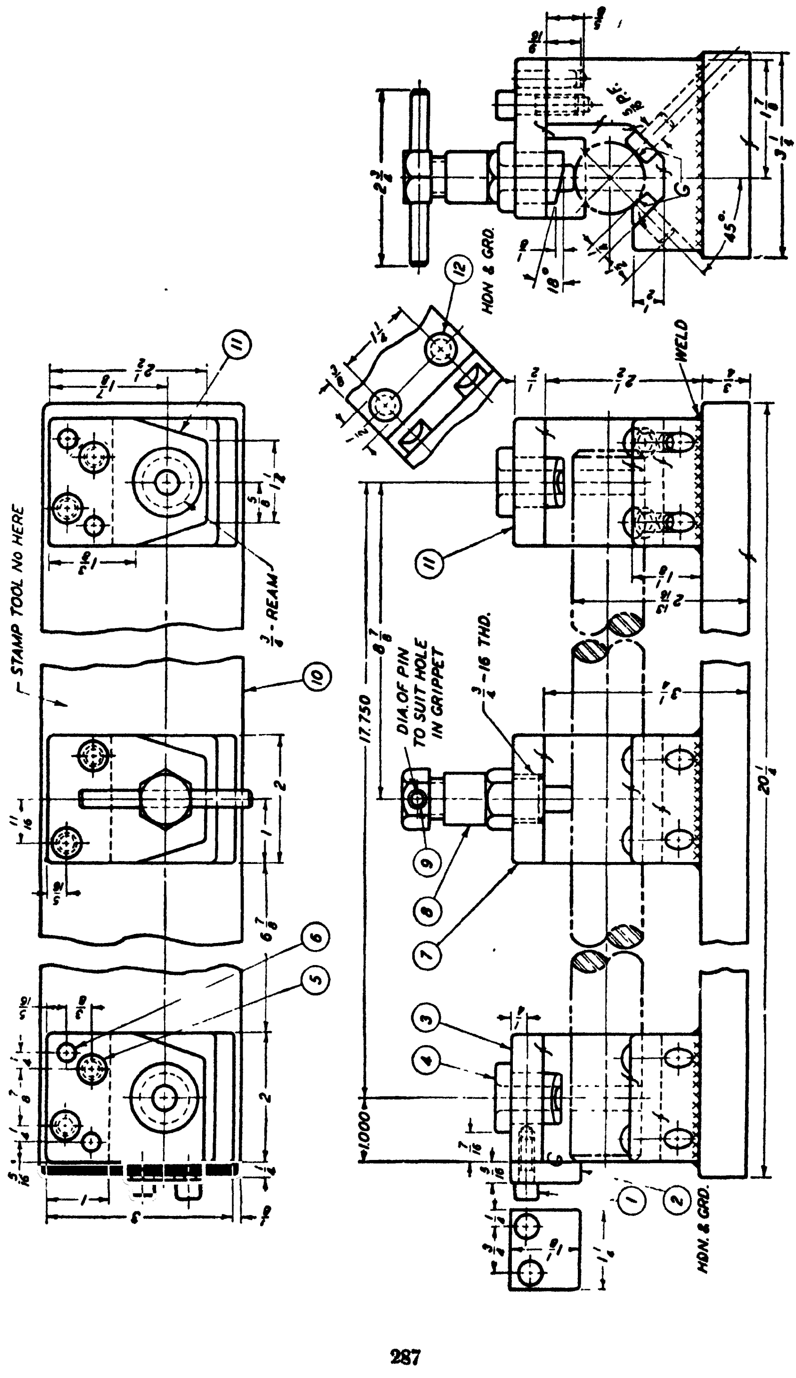


Fig. 21A. Drill Jig for Drilling Holes in Sprocket Shaft

are drilled entirely through to the outside of the V-block in order to provide means for knocking out these rest pins when they become worn. The clamping screw is provided in the center because the *shaft is of large diameter.* This design of jig is very inexpensive to design and make, and is very satisfactory for drilling shafts of this type in small quantities.

NO	REQ.	DESCRIPTION	MATERIAL	SIZE
12	12	REST PINS	KETOS T ST. HDN. & GRD	$\frac{5}{8} \times \frac{7}{8}$ LG.
11	1	BUSHING PLATE	MACH ST.	$\frac{5}{8} \times 2\frac{1}{8} \times 2\frac{5}{8}$
10	1	BASE	MACH ST.	TO SUIT
9	1	PIN		SEE NOTE
8	1	GRIPPET, G-58	PURCHASED	ILL. TOOL CO.
7	1	GRIPPET PLATE	MACH ST	$\frac{5}{8} \times 2\frac{1}{8} \times 2\frac{5}{8}$
6	4	DOWEL PINS	STANDARD	$\frac{5}{16}$ DIA. × 1
5	6	SOCKET HEAD SCREW	STANDARD	$\frac{5}{16}$ - 18 × 1
4	2	DRILL BUSHG. #L-13	EX-CELLO	FOR $\frac{25}{64}$ DRILL
3	1	BUSHING PLATE	MACH ST.	$\frac{5}{8} \times 2\frac{1}{8} \times 2\frac{5}{8}$
2	1	GAGE PLATE	KETOS T. ST. HDN. & GRD.	$\frac{3}{8} \times 1\frac{1}{4} \times 1\frac{3}{8}$
1	2	SOCKET HEAD SCREW		$\frac{1}{4}$ - 20 × $\frac{3}{4}$

Fig. 21B. Bill of Materials for Fig. 21A

CAM DRILL JIGS

For drilling certain types of screw machine parts, particularly for a collar in which it is necessary to drill and tap a hole for locking screw, a quick-acting cam jig, Figs. 22A and 22B, can be designed to handle piece parts very rapidly in the drilling and tapping operations.

The base of this jig (*3*) is made of machine steel, and to it are welded upright *1* made of cold-rolled steel and upright *2* of cold-drawn steel. After normalizing, the bottom of the jig base and the two uprights are machined to the correct dimensions. A bushing plate (detail *4*) is fastened and located on one of the uprights by means of dowel pins (*6*) and socket-head cap screws (*5*) A plug (detail *8*) is designed with three hardened and ground rest pins (*9*) inserted to act as a stop and locator for the piece part. The cam (detail *10*) is designed to be made of machine steel and is welded onto the cam handle (detail *11*). This construction is

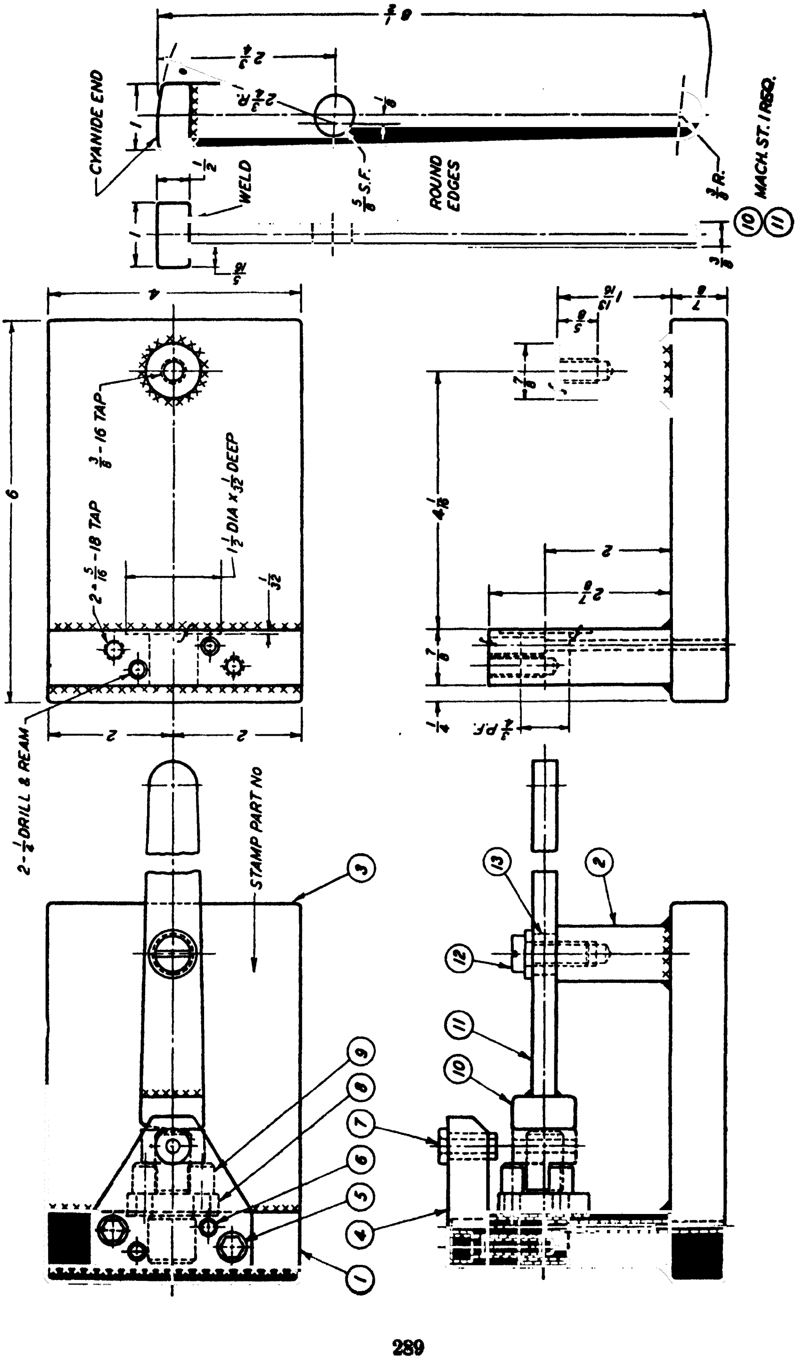
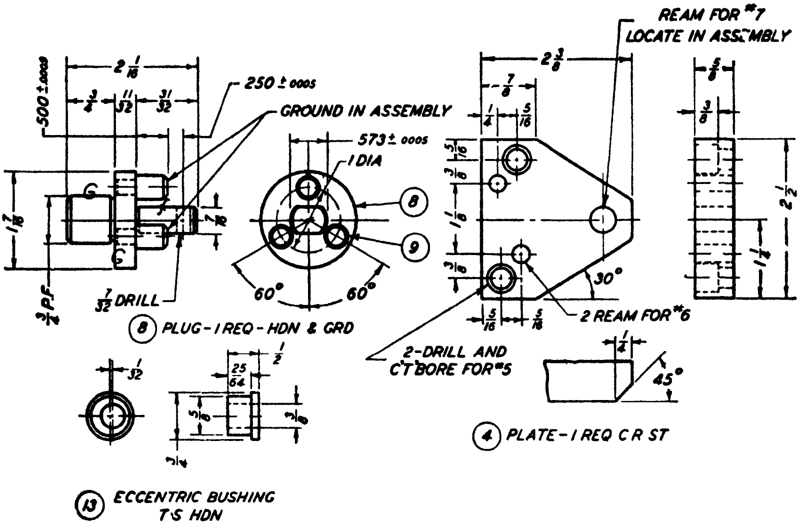


Fig. 22A. Drill Jig for Drilling a Hole in Pulley Screw Collar

cheaper than if this entire cam and cam lever had been made out of one solid piece of steel

The cam handle is attached to upright section *2* that is welded to the jig base, and an eccentric bushing (detail *13*) is designed to



NO	REQ	DESCRIPTION	MAT'L	SIZE
1	1	WELDED BASE	C R ST	$\frac{7}{8}$ x 3 x 4
2	1		C D ST	$\frac{7}{8}$ DIA x 2
3	1		MACH ST	1 x 4 x 6$\frac{1}{4}$
4	1	BUSHING PLATE	C R ST	$\frac{5}{8}$ x 2$\frac{1}{2}$ x 2$\frac{1}{2}$
5	2	SOCK HD CAP SCR	ST'D	$\frac{5}{16}$ -18 x 1$\frac{1}{8}$
6	2	DOWEL	ST'D	$\frac{1}{4}$ DIA x 1$\frac{1}{2}$
7	1	BUSHING	XLO #0-611-A FOR $\frac{17}{64}$ DRILL	
8	1	PLUG	DR ROD	1$\frac{1}{2}$ DIA x 2$\frac{1}{4}$ – HDN & GRD
9	3	PIN	DR ROD	$\frac{3}{8}$ DIA x 1 – HDN & GRD
10	1	CAM	MACH ST	$\frac{5}{8}$ x 1 x 1
11	1	CAM HANDLE	MACH ST	$\frac{3}{8}$ x 1 x 8$\frac{1}{4}$
12	1	FL FILL HD SCR	ST'D	$\frac{3}{8}$ -16 x 1
13	1	ECCENTRIC BUSH	T S	[illegible]

Fig 22B. Details and Bill of Materials for Drill Jig Shown in Fig 22A

be inserted through the cam lever handle. This bushing is made eccentric so that, if wear takes place on the cam face, the bushing can be shifted in the lever so as to compensate for the wear. This is good construction and prevents replacements that would ordinarily occur through the pressure exerted in clamping the piece part in the jig. This jig allows very fast operation, and designs similar to this can be employed for a great many small parts

SWINGING CLAMP DRILL JIGS

For second operations on screw machine parts, swinging clamp drill jigs are frequently designed, particularly for drilling holes at right angles to the axis of the piece part. In the design shown in Fig. 23A, the body of the jig is cast iron, machined on the necessary sections for insertion of the adapter and the jig feet, which are made

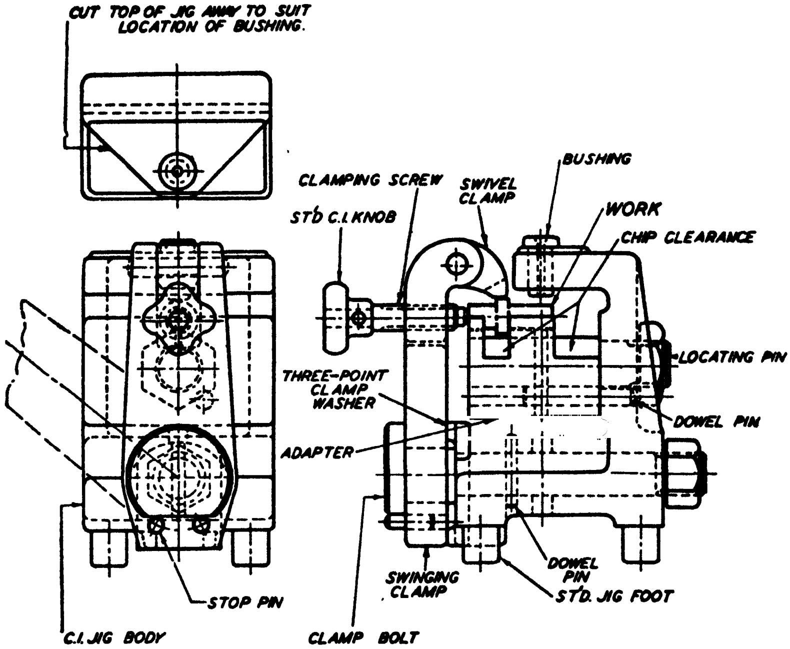


Fig. 23A. High-Production Drill Jig for Drilling Piece Parts Made in a Screw Machine

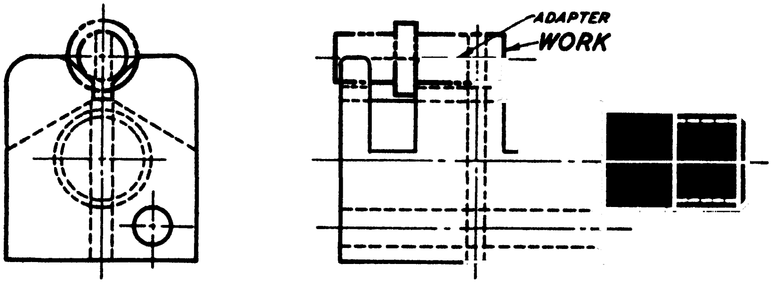


Fig. 23B. Enlarged View of Adapter and Work for the Jig Shown in Fig. 23A

of hardened steel to prevent wear. The clamp itself is designed to be a casting with a hardened swivel clamp. The swinging clamp, as you will note from the drawing, swings to one side and is prevented by a stop pin from dropping to the drill-press table. The adapter is shown in Fig. 23B. One advantage of jigs of this design is that an interchangeable adapter could be used, and a liner bushing could be inserted in the bushing plate so that different sizes of drill bushings could be inserted to take care of various piece parts of approximately the same over-all dimensions. Numerous adaptations of this design can be employed for drilling screw-machine parts.

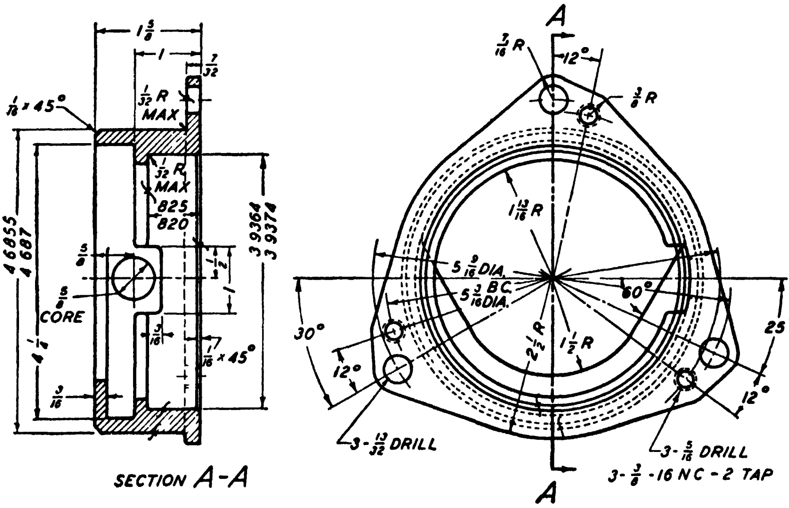
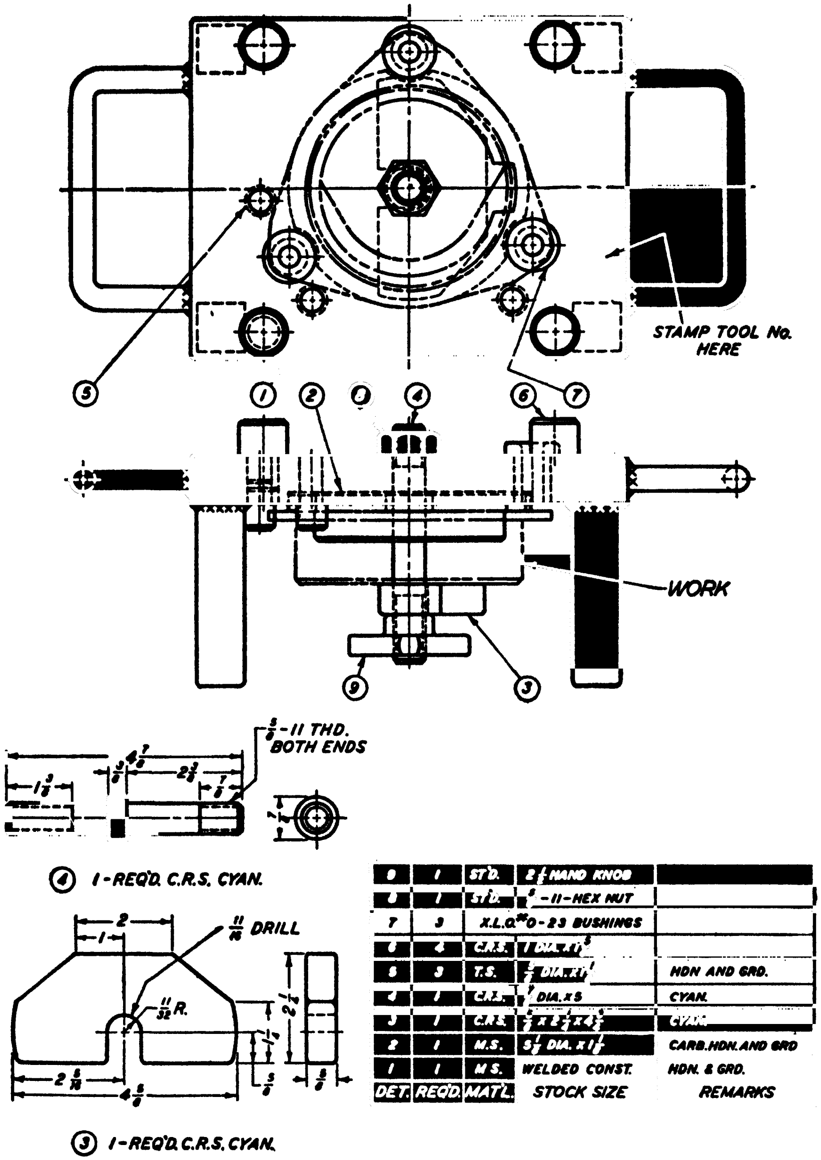


Fig 24. Transmission Spline Shaft Bearing Cage

For a piece part similar to Fig. 24, which is a transmission spline shaft bearing cage for use where production quantities are low, a jig similar to Fig. 25 is frequently designed. This shows the assembly of a completed jig, and details *3* and *4*. Fig. 26 shows the remaining details of the design. In this type of jig the piece part is located by means of a plug (*2*) underneath the bushing plate. The drilling is done against the clamp (*3*), which is not considered good practice; but, where production is low, jigs of this design are sometimes made on account of their low cost.

The three 13/32″ holes in the flange of this piece part, Fig. 24, could be drilled in a patented quick-acting jig to much better ad-



DET.	REQ'D.	MAT'L.	STOCK SIZE	REMARKS
9	1	ST'D.	$2\frac{1}{2}$ HAND KNOB	
8	1	ST'D.	$\frac{5}{8}$-11-HEX NUT	
7	3	X.L.O. #0-23 BUSHINGS		
6	4	C.R.S.	1 DIA. x $1\frac{5}{8}$	
5	3	T.S.	$\frac{5}{8}$ DIA. x $1\frac{1}{8}$	HDN AND GRD.
4	1	C.R.S.	$\frac{7}{8}$ DIA. x 5	CYAN.
3	1	C.R.S.	$\frac{5}{8}$ x $2\frac{1}{4}$ x $4\frac{5}{8}$	CYAN.
2	1	M.S.	$5\frac{1}{2}$ DIA. x $1\frac{1}{8}$	CARB. HDN. AND GRD
1	1	M.S.	WELDED CONST.	HDN. & GRD.

Fig. 25. Drill Jig to Drill Three Holes in the Piece Part Shown in Fig. 24

vantage. However, the cost of that jig in this particular case would be too high. Therefore it is necessary to design a jig that is less expensive. By referring to the drawing of the piece part, Fig. 24, it

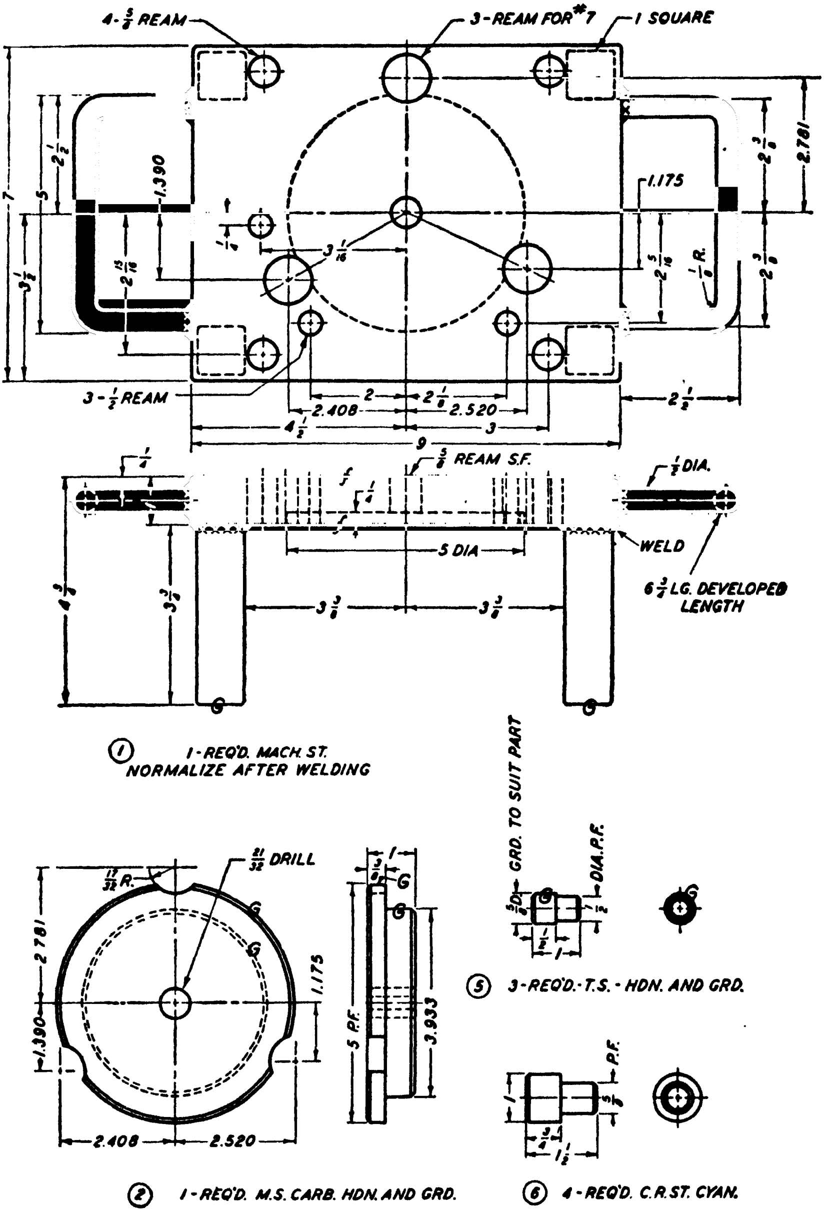


Fig. 26. Details of the Design Shown in Fig. 25

will be noted that the flange in which the three $^{13}/_{32}$" holes are to be drilled is triangular in shape, and that it is necessary to locate the piece part on the face of the flange and concentric with the central bore, which is 3.9374" in diameter.

The distance from the back of this piece part to the flange face is 1⅝"; if the piece were located so that the drilling would take place from the rear, it would mean that drills of extra length would have to be employed. Therefore this piece part is drilled from the face of the flange.

Referring again to Fig. 26 which shows the details of construction of this drill jig, detail *1* consists of a bushing plate with four legs 1" square welded to it. To make it simple for the operator to handle this jig, handles are welded on either side. This enables the operator to hold this jig and move it around on the table of a single-spindle drill press to drill the three $^{13}/_{32}$" diameter holes.

Three hardened and ground locating pins (detail *5*) are pressed into three ½" reamed holes in the bushing plate in order to locate the piece part so that the holes in the flange will be drilled in the proper location. This insures that the piece will be inserted properly in the jig each time. A stud (detail *4*, of Fig. 25) is designed to accommodate the clamp (*3*), and a cast-iron hand knob (detail *9*) is provided for tightening the clamp against the work after it has been inserted over this stud. The piece part shown in Fig. 24 is a very good illustration of the fact that in designing drill jigs numerous designs can be employed. It also illustrates thoroughly the point that the production quantity is often the determining factor in deciding what type of jig will be used. There are at least four types that could be designed for drilling this particular piece part; each would be correct; the selection would be determined by the quantity of piece parts to be produced.

BOX DRILL JIGS

When it is necessary to design a drill jig for drilling holes in two or more sides of a piece part, a box drill jig or an index jig is generally used. Fig. 27 shows a drawing of a work piece that is drilled on three sides and in addition has two angular holes. As you will note from this drawing, the center to center distance of the two $^{9}/_{16}$" reamed holes is within very close limits, being given in decimal dimensions; therefore the jig for drilling and reaming a piece part of this kind must be carefully designed and the piece must be located so that all holes will be in definite relation to each other. For these reasons, a box jig, Figs. 28A and 28B, is designed. In these illustrations are shown the various views of this design of jig. The body (*1*) is made of cast iron and one side (at *A*) has been machined to a 30° angle; the other side (at *B*) has been machined to a 17° angle. These angular surfaces provide bases so that the jig can be tilted to the required angle on each side to drill the two angular holes at *C*. This piece part has been milled on two sides so that accurate locating in the jig is simplified.

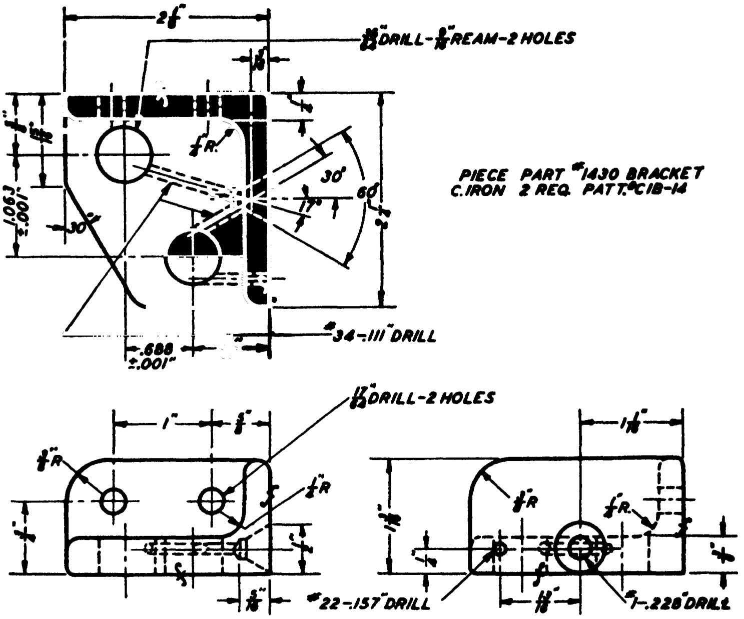
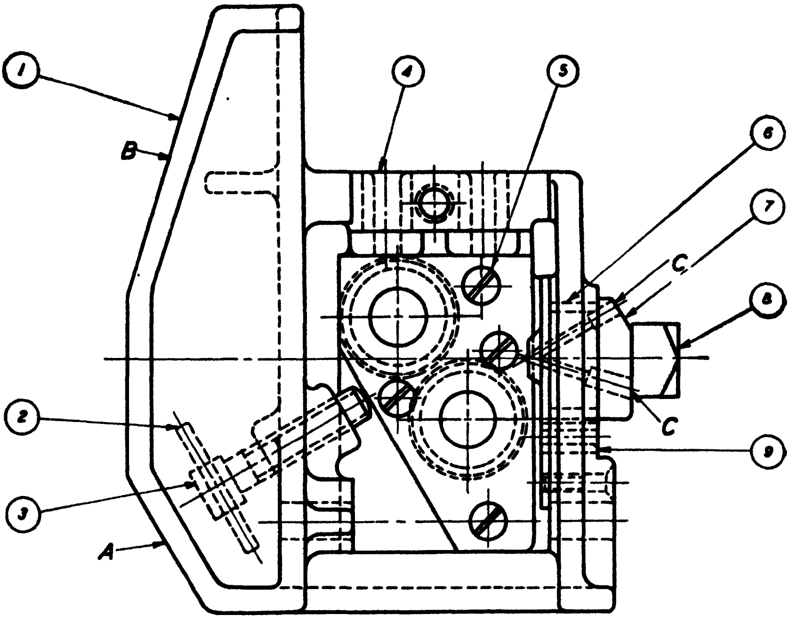


Fig 27. Working Drawing of Bracket Machined in Box Jig Shown in Figs. 28A and 28B

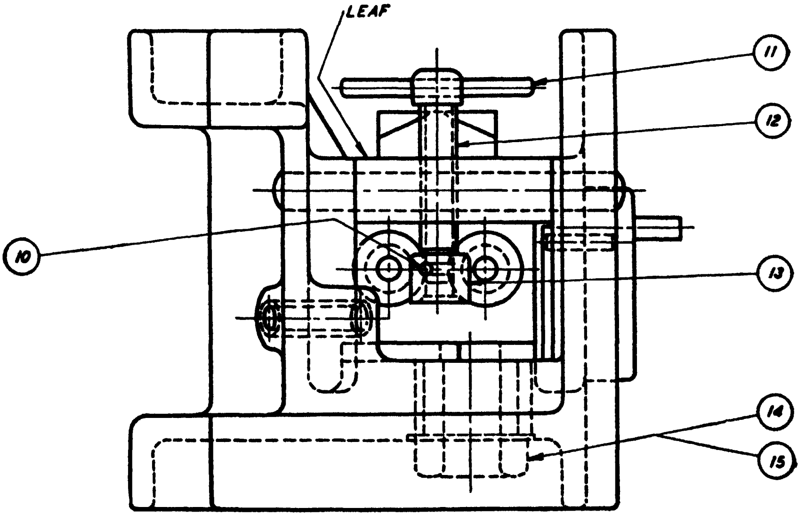
In the plan view of Fig. 28A it will be seen that a clamping screw (*3*) has been provided in the angular portion of this jig for locking the piece part against positive stops. In the front elevation an additional screw (*12*) has been provided with a floating equalizer (*13*) to lock the piece against any possibility of movement when the drilling operation is being performed.

The bill of materials for this jig, Fig. 29, may be used to identify



PLAN

PLAN VIEW SHOWS LEAF PLATE REMOVED

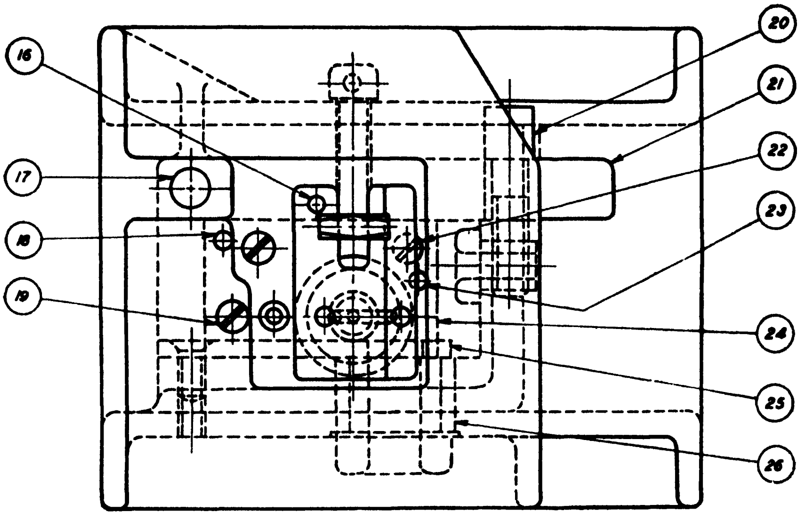


FRONT ELEVATION

Fig. 28A. Box Drill and Ream Jig for Machining Holes from Three Sides and at an Angle

the various details. Studying the layout of the assembly drawings that are shown in these illustrations and referring to the bill of materials will give the tool designer a very good idea of this design.

Box jigs have an outstanding advantage when all the holes in the piece part are the same size range and within the capacity of the drill press. However, where very large holes or very small holes are in the same piece part, it is considered good practice to design two jigs, as small drills will not run efficiently in a drill press that would have the capacity to drill 1″ to 1½″ holes. For example, where both 1½″ and ¼″ holes were in the same piece part it would be more efficient to drill all the large holes in one jig and then locate from these holes and drill the small holes in another jig, of course using a smaller drill press.



RIGHT SIDE ELEVATION

Fig. 28B. View of the Box Drill and Ream Jig Shown in Fig. 28A

On certain types of large work it is sometimes necessary to ignore this rule because of the fact that the size of the drill jig and the piece part are such that the drilling operations must be performed in a radial drill press. If this is the case, the design of a modern radial drill press is such that speeds and feeds of the drills can readily be changed by the operator because these controls are at the drill head that slides on the radial arm of the drill press.

BILL OF MATERIALS

DET. NO.	DESCRIPTION	NO. REQ.	MAT.	FIN. STOCK SIZE	PATT NO.
1	JIG BODY	1	C. IRON		S-4421
2	CLAMPING SCREW PIN	1	C.R. ST.	5/8" DIA. X 1 1/2" LG.	
3	CLAMPING SCREW	1	STANDARD	3/8"-16 N.C. X 1 3/4" LG.	
4	DRILL BUSHING	2	XLO-ST'D.	13/32" INSIDE DIA. X 5/8" LG.	
5	FLAT HEAD MACH. SCREW	4	STANDARD	1/4"-20 N.C. X 5/8" LG.	
6	LINER BUSHING	1	XLO-ST'D.	1" INSIDE DIA. X 1/2" LG.	
7	DRILL PLATE	1	TOOL ST.	1 5/8" X 1 1/2" X 2" LG.	
8	QUARTER TURN THUMBSCREW	1	C.R. ST.	1/2" X 3/4" X 1 5/8" LG.	
9	HEADLESS DRILL BUSHING	1	STANDARD	#22-.157" INSIDE DIA. X 5/16"	
10	FLOATING CLAMP PIN	1	DR. ROD	#31-.1200" DIA. X 15/16" LG.	
11	TOP CLAMPING SCREW PIN	1	C.R. ST.	5/16" DIA. X 2" LG.	
12	TOP CLAMPING SCREW	1	C.R. ST.	1/2" SQUARE X 2 1/2" LG.	
13	TOP CLAMPING SCREW FLOAT	1	DR. ROD	3/4" DIA. X 1/2" LG.	
14	SLIP DRILL BUSHING	1	XLO-ST'D.	13/32" INSIDE DIA. X 3/4" LG.	
15	SLIP REAM BUSHING	1	XLO-ST'D.	3/8" INSIDE DIA. X 3/4" LG.	
16	DRILL PLATE PIN	1	ST'D. DOWEL	3/16" DIA. X 1/2" LG.	
17	CLAMP PIVOT PIN	1	C.R. ST.	1/4" DIA. X 3 11/16" LG.	
18	DOWEL PIN	1	STANDARD	3/16" DIA. X 3/4" LG.	
19	FLAT HEAD MACH. SCREW	1	STANDARD	#10-.190" N.C. X 3/4" LG.	
20	QUARTER TURN THUMBSCREW	1	C.R. ST.	1/2" X 1 1/2" X 2" LG.	
21	LEAF PLATE	1	C.R. ST.	3/8" X 2" X 4 3/4" LG.	
22	FLAT HEAD MACH. SCREW	2	STANDARD	#10-.190" N.C. X 5/8" LG.	
23	DOWEL PIN	1	STANDARD	3/16" DIA. X 5/8" LG.	
24	SIDE GAGE PLATE	1	TOOL ST.	1/2" X 1 5/16" X 2 5/16" LG.	
25	BOTTOM GAGE PLATE	1	TOOL ST.	5/16" X 2" X 3 5/16" LG.	
26	LINER BUSHING	2	XLO-ST'D.	1" INSIDE DIA. X 3/4" LG.	
27	DRILL BUSHING	1	XLO-ST'D.	#1-.228" DIA. X 5/8" LG.	
28	SLIP DRILL BUSHING	1	XLO-ST'D.	17/32" INSIDE DIA. X 9/16" LG.	
29	SLIP COUNTERSINK BUSHING	1	XLO-ST'D.	1/2" INSIDE DIA. X 1/2" LG.	

Fig. 29. Bill of Materials for Box Jig Shown in Figs. 28A and 28B

The piece part shown in Figs. 30A and 30B is a water-pump body for an internal combustion engine and is a good illustration of the type of work that requires more than one jig to complete the necessary operations. As will be noted from the drawing, there are a number of holes of various sizes. While it would be possible to drill most of these holes in a box jig, the difference in their size and location makes it rather difficult to design a jig that would be capable of drilling all holes and obtain efficient production. Note that there are four $^{15}/_{32}''$ holes to be drilled in the base of this part. Two drain holes are to be drilled at an angle in the water-pump body; these are $^{3}/_{16}''$ and $^{1}/_{8}''$ in diameter. There is also a $^{1}/_{8}''$ hole to be drilled in the hub of the water-pump body. These operations can best be performed by the use of three jigs as described in the following paragraphs.

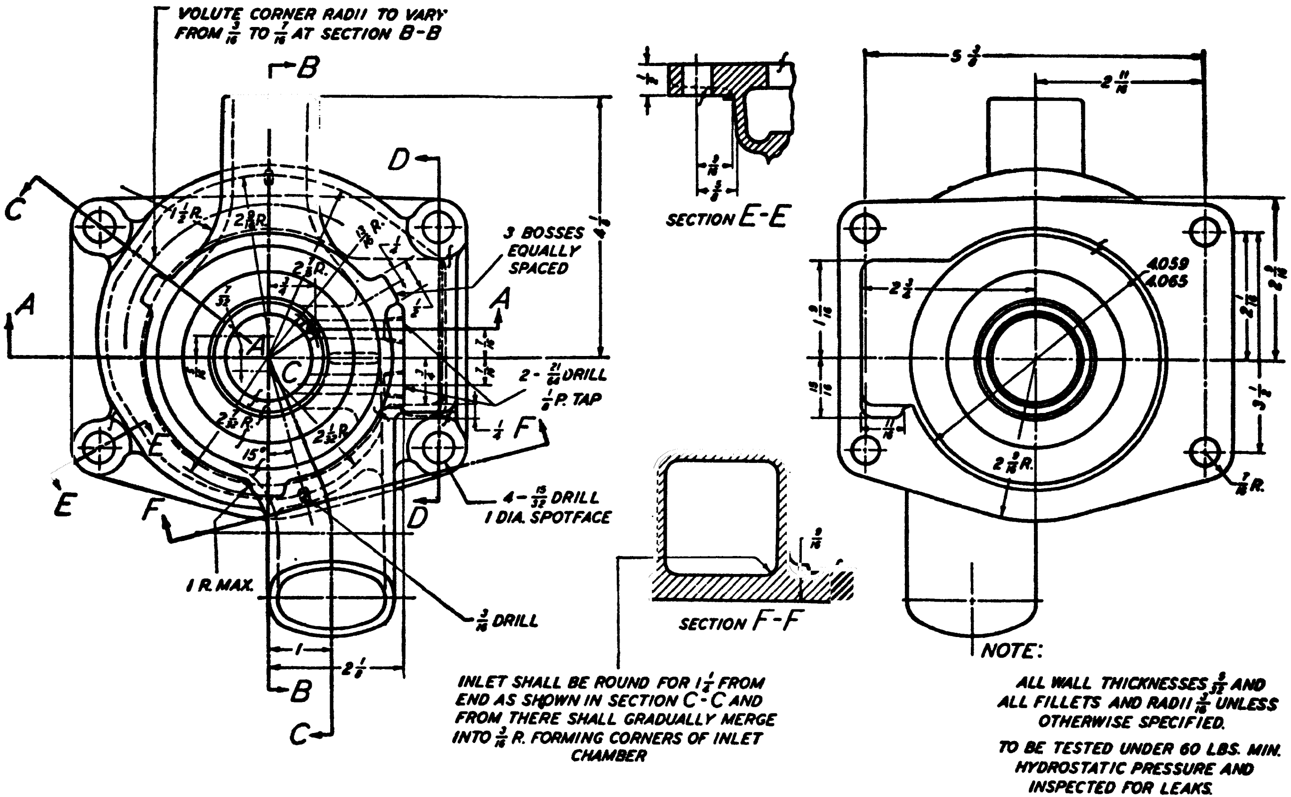
The drawing of this piece part should be given considerable study by the tool designer so that he can design the right type of jigs to perform the necessary operations.

The four $^{15}/_{32}''$ holes that are drilled in the base of this part are drilled in a separate jig of a very simple design which is not shown here because designs of similar jigs have already been explained and illustrated.

Fig. 31A is the assembly drawing of a jig to drill two drain holes in the water-pump body. One hole is $^{3}/_{16}''$ in diameter (shown in Fig. 30A) and one is $^{1}/_{8}''$ in diameter, shown in Fig. 30B. These holes come in at different angles and are located in the inlet and outlet ends of the pump body. In the assembly drawing, Fig. 31A, it will be noted that the jig is made of steel and the sections are welded together to obtain a jig as light and strong as possible. Fig. 31B is the bill of materials.

Fig. 32 is a drawing illustrating the details of construction of the jig body (detail *1*). You will note from this drawing that the bushing plates are set on an angle to locate the drill bushings. This jig body is made of machine steel and after the welding operations have been performed it should be normalized (or strain annealed) by heating in a furnace until the required temperature is reached, then allowed to cool. This is to prevent warping and distortion. After this the jig body is machined to the required dimensions.

Welded steel construction was specified in designing this jig



INLET SHALL BE ROUND FOR $1\frac{1}{4}$ FROM END AS SHOWN IN SECTION C-C AND FROM THERE SHALL GRADUALLY MERGE INTO $\frac{3}{16}$ R. FORMING CORNERS OF INLET CHAMBER

NOTE:

ALL WALL THICKNESSES $\frac{5}{32}$ AND ALL FILLETS AND RADII $\frac{3}{16}$ UNLESS OTHERWISE SPECIFIED.

TO BE TESTED UNDER 60 LBS. MIN. HYDROSTATIC PRESSURE AND INSPECTED FOR LEAKS.

Fig 30A. Water-Pump Body for an Internal Combustion Engine

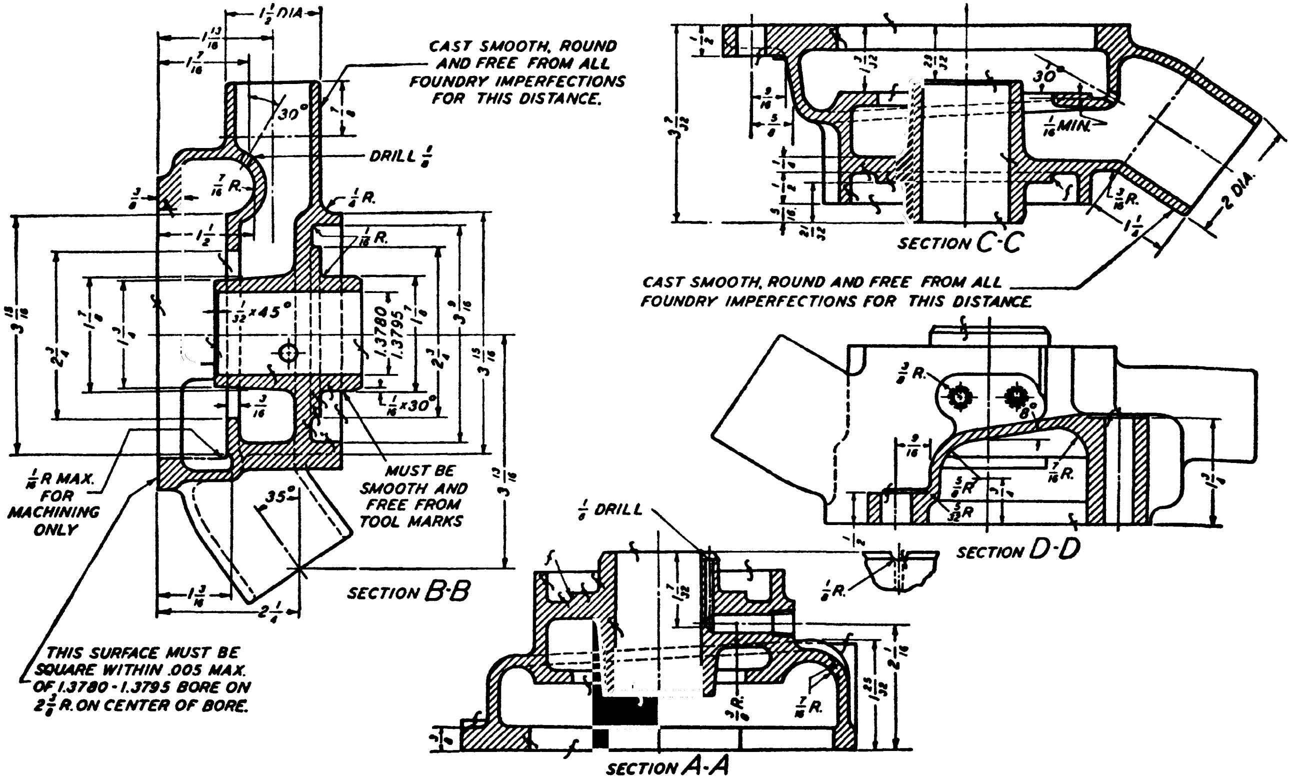


Fig. 30B. Sections of the Design Shown in Fig. 30A

because the cost of a pattern and casting for a jig of this type would be considerably higher than a welded steel body.

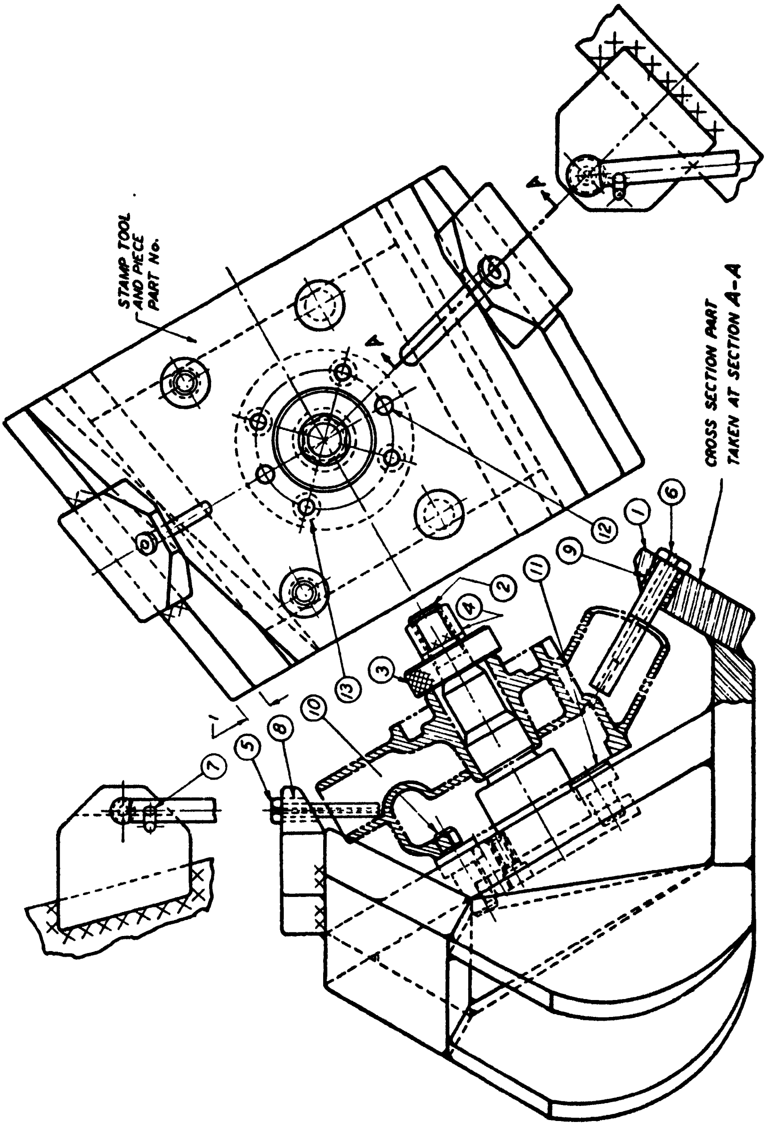

STAMP TOOL AND PIECE PART No.
A
A
CROSS SECTION PART TAKEN AT SECTION A-A
6
1
12
9
11
2
4
3
13
10
8
5
7

Fig. 31A. Assembly Drawing of a Jig to Drill Two Drain Holes in a Water-Pump Body

Fig. 33 illustrates the design of the details of the jig. Detail *2* is the locating plug. The piece part is slipped on this and fastened by means of a **C**-washer (detail *3*) and a nut (detail *4*). In view of the fact that the bushings must extend down into the inlet and outlet portions of this water-pump body, extra length drill bushings must be designed and made. However, the liner bushings used are standard. You will note that the drill bushings (details *5* and *6*) have been relieved by putting in a larger hole (5/32″) than the drill size. In detail *5*, 3/4″ has been allowed for the guiding of a 1/8″ drill. In detail *6*, the same amount, 3/4″, has been allowed for guiding the 3/16″ drill. Because of the fact that it is necessary to remove these drill bushings from the jig body in order to load and unload the piece part, handles are welded onto the bushings to permit the operator to remove them with the least possible effort.

NO.	REQ.	DESCRIPTION	MATERIAL	SIZE
1	1	WELD	MACH. ST.	TO SUIT
2	1	CARB., HDN. & GRD.	MACH ST.	4 DIA. x 6 $\frac{1}{2}$
3	1	C-WASHER	MACH ST.	2 $\frac{1}{4}$ DIA. x $\frac{3}{4}$
4	1	ST'D HEX. NUT & C.R ST. WASHER		$\frac{3}{4}$ - 10
5	1	HDN. & GRD.	TOOL ST.	$\frac{9}{16}$ DIA. x 2 $\frac{5}{8}$ FOR BUSHING
6	1	HDN. & GRD.	TOOL ST.	$\frac{13}{16}$ DIA x 3 $\frac{5}{8}$ FOR BUSHING
7	2	STOP PIN	C.R. ST.	$\frac{1}{4}$ DIA. x 1 $\frac{3}{8}$
8	1	XLO LINER BUSH.	ST'D.	#IS-41
9	1	XLO LINER BUSH.	ST'D.	#IS-42
10	1	LOCATOR	ST'D.	.463 DIA. JS #245
11	3	REST BUTTON	ST'D.	JS #229
12	2	DOWEL	ST'D.	$\frac{3}{8}$ DIA. x 1 $\frac{1}{2}$
13	4	SOCK. HD SCR.	ST'D.	$\frac{3}{8}$ - 16 x $\frac{3}{4}$

CUTTING TOOLS USED	
1	$\frac{3}{16}$ - H.S. DRILL - STRAIGHT SHANK, 7 OVER ALL
1	$\frac{1}{8}$ - H.S. DRILL - STRAIGHT SHANK, 6 OVER ALL

Fig. 31B. Bill of Materials for the Design Shown in Fig. 31A

By referring to section *A-A* of Fig. 30B, it will be seen that there is a 1/8″ hole drilled in the hub of this water-pump body. A separate jig is designed as shown by Fig. 34 to drill this hole. This drawing shows that this is a simple jig with a bushing plate (detail *1*) in which a plug (detail *2*) is inserted. This plug is made of tool steel hardened and ground to fit the central bore of the water-pump body. The plug is ground to 1.375″ diameter and is chamfered

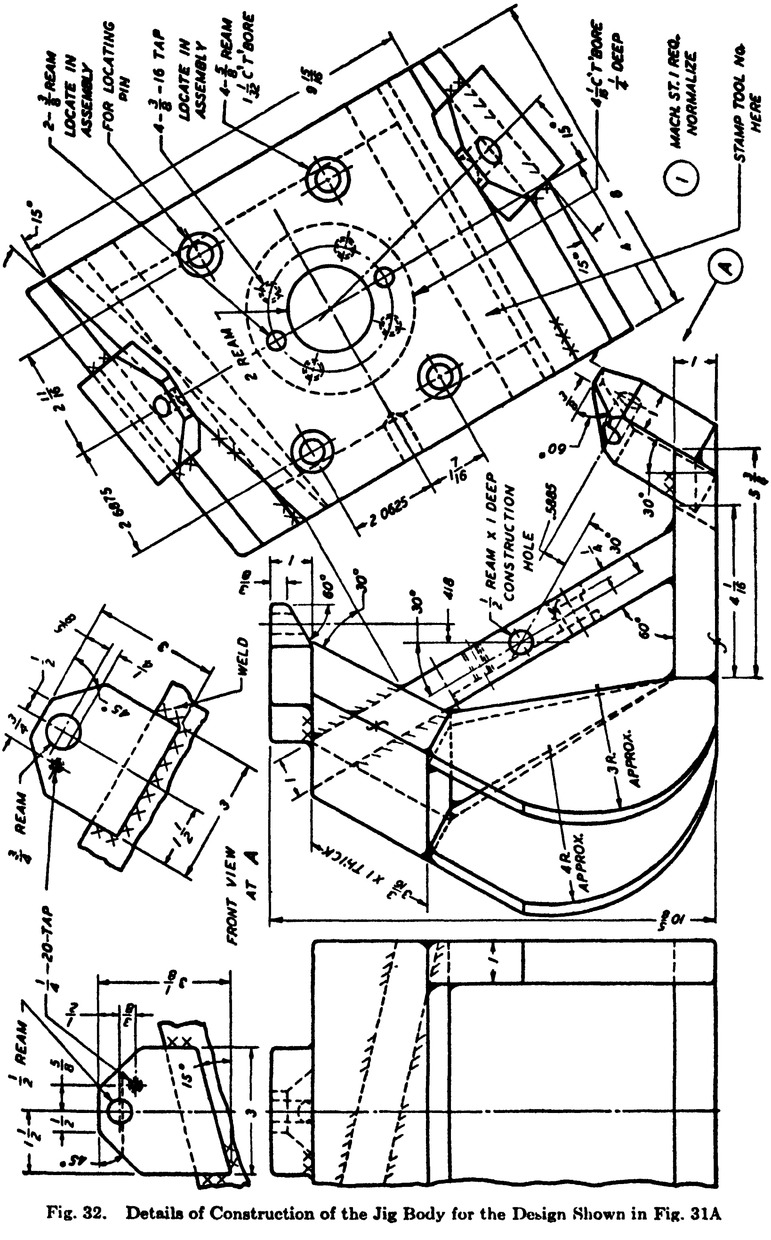


Fig. 32. Details of Construction of the Jig Body for the Design Shown in Fig. 31A

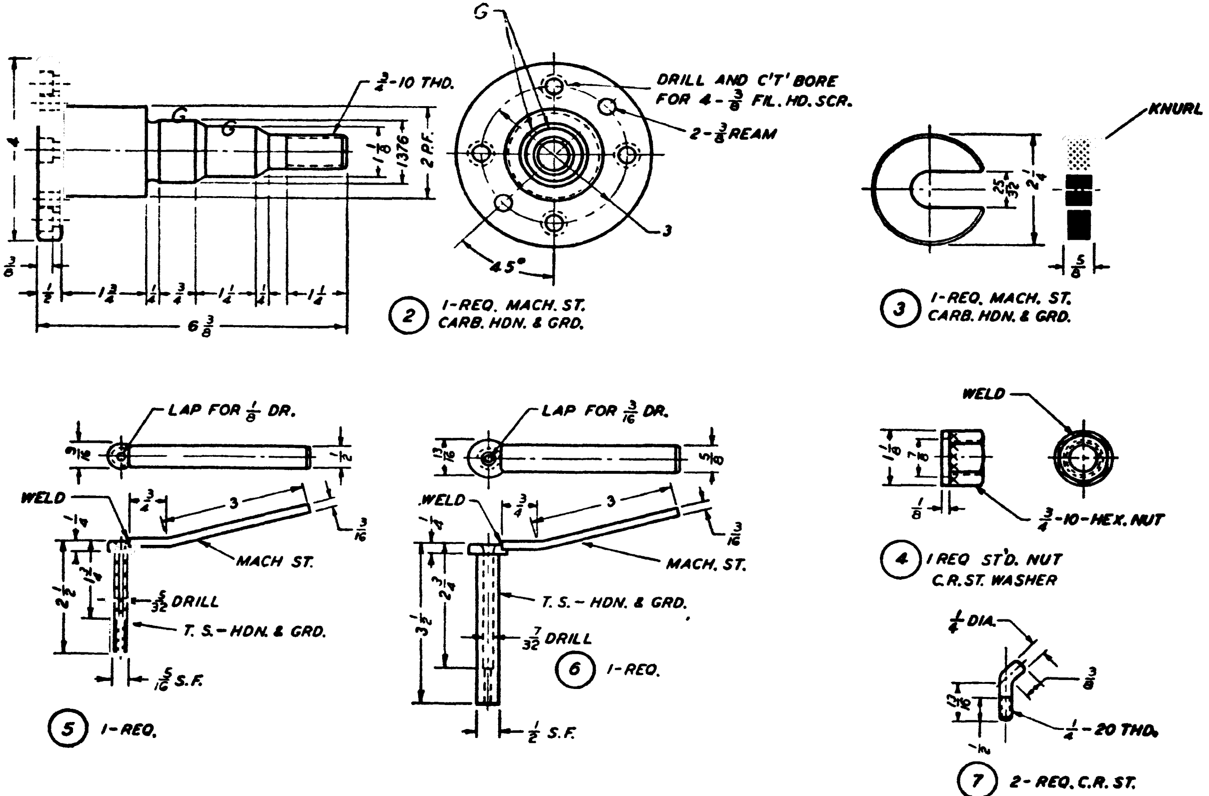
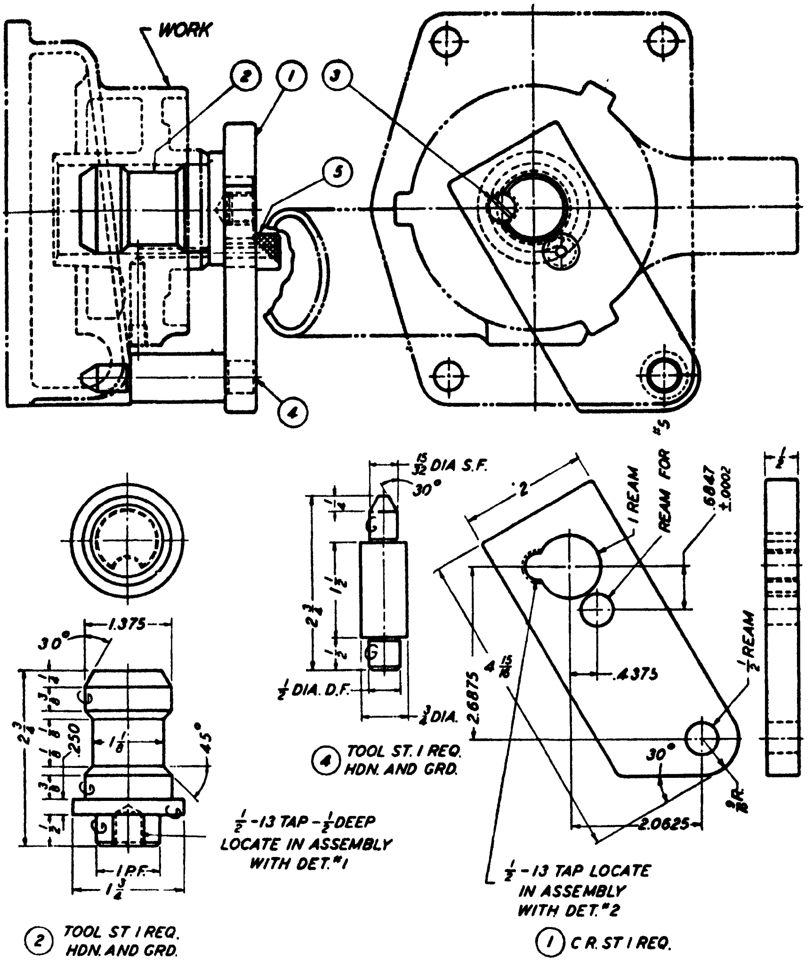


Fig. 33. Details of the Jig Shown in Fig. 31A



NO	REQ.	SIZE	MATERIAL	REMARKS
5	1	.125 DRILL × 1/2 LG.	STD. X L.O. BUSHING	
4	1	3/4 DIA. × 2 7/8	TOOL ST.	HDN. & GRD.
3	1	1/2-13 × 3/8	HEADLESS SET SCREW	
2	1	1 3/4 DIA. × 2 7/8	TOOL ST.	HDN. & GRD.
1	1	1/2 × 2 × 5 1/16	C.R. ST.	

REQ.	TOOLS USED	NO.
1	1/8 DRILL, STRAIGHT-SHANK	

Fig. 34. Jig to Drill 1/8" Hole in Hub of Water-Pump Body Shown in Fig. 30A

for 1/4″ at a 30° angle to permit easy insertion into the central bore in the hub section of this water-pump body.

On one end of the bushing plate is an additional locating plug, detail *4*. This plug is designed to be made of tool steel and is hardened and ground. It locates in one of the 15/32″ drill holes in the base of the water-pump body. This provides for an accurate location for the 1/8″ drill bushing (*5*) that is inserted in the plate (*1*). This type of jig is frequently used as an auxiliary jig on large parts where it would not be good design practice to use a single, more elaborate jig to provide for all the operations.

By referring to Fig. 30A, the piece part, it will be noted that there are two 21/64″ holes to be drilled, and then tapped with 1/8″ standard pipe tap. These holes are located on the hub of the water-pump body. To perform this operation a jig is designed similar to that shown as Fig. 35A. Fig. 35B shows design of the details; Fig. 35C is the bill of materials.

In this jig the angle plate or body (*1*) is made out of a gray iron casting which of course requires a pattern. The bushing plate (*3*) is made of machine steel and is attached to the top of the angle plate by means of hexagon head cap screws (*12*) and dowel pins (*13*). The locating plug (detail *2*) is designed to be made of machine steel. It is carburized, hardened and ground, and the work slips over the 1.376″ diameter. This plug is provided with a **C**-washer (detail *4*) and a nut (detail *5*) for clamping the piece part in against the face of the angle plate. You will note that this nut is small enough across the hexagon so that, when the **C**-washer is removed, the piece part can be withdrawn from the jig without any interference.

A standard locating pin (*10*) is provided to locate in one of the 15/32″ holes in the base of the water-pump body. This pin is designed so that it is a combination locating pin and rest pad. Three additional standard rest buttons (*11*) are provided in the face of this angle plate. These rest buttons are hardened and ground and provide a resting surface for the work piece. In this design a standard slip drill bushing (*8*) is used, but on account of the fact that the drill bushing must be removed, liner bushings (*9*) are provided in the bushing plate. On account of the close center distance of these two drilled holes, it is necessary to flatten off a portion of

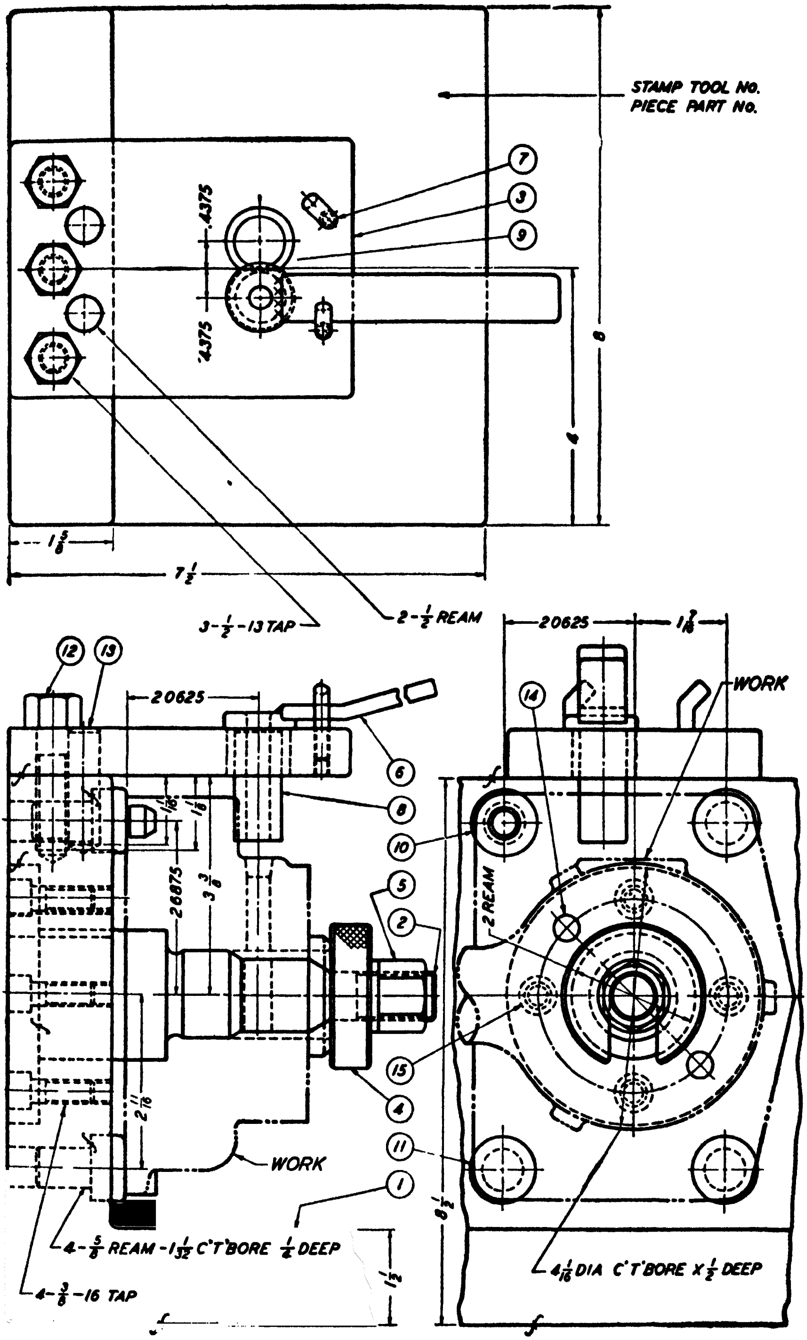


Fig. 35A. Jig to Drill and Tap Two 1/8" Pipe Tap Holes in the Water-Pump Body Shown in Fig. 30A

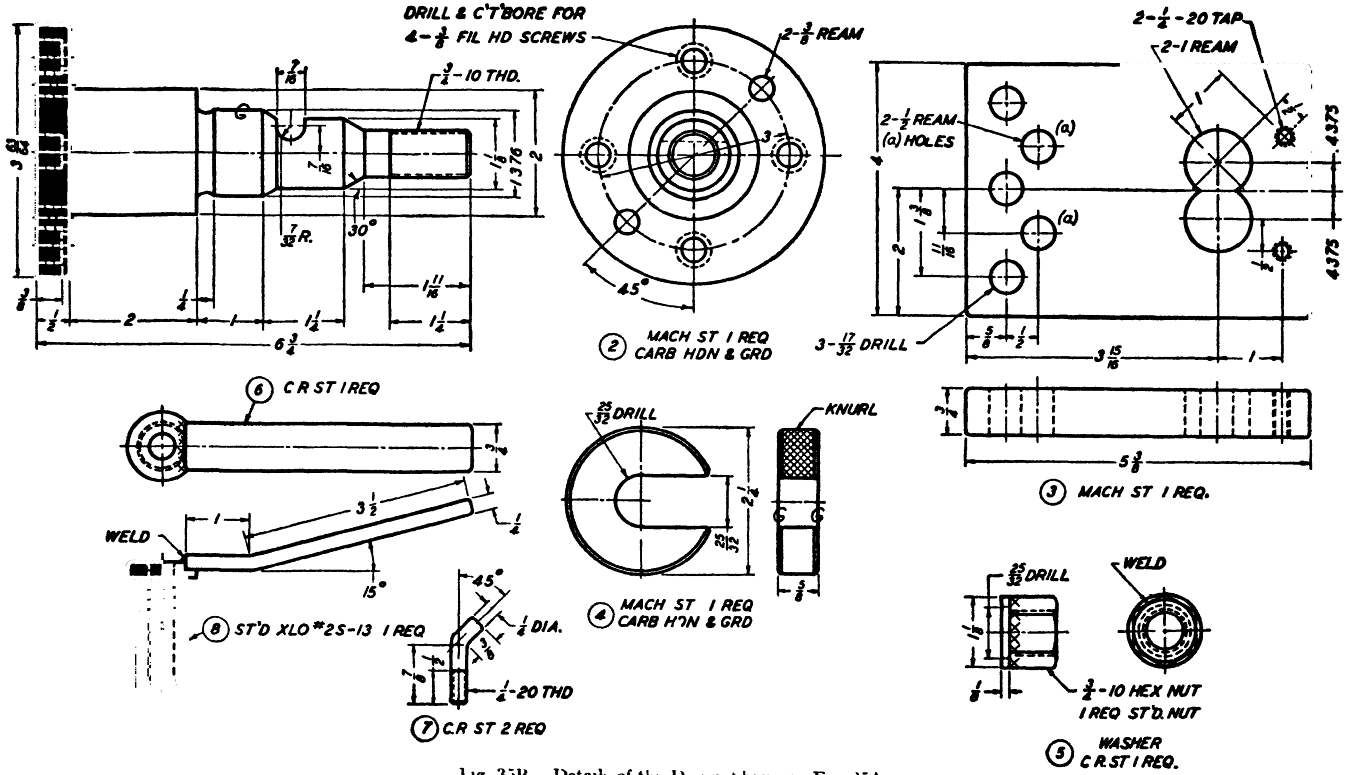


Fig. 35B. Details of the Design Shown in Fig. 35A

the liner bushings to allow the correct spacing, which is .4375″. Note that it is necessary to have only one slip drill bushing, with a handle (*6*) welded on it for easy removal of the bushing. After one hole has been drilled, the bushing is transferred to the other hole. After this second hole has been drilled with a $^{21}/_{64}$″ drill, the tapping is done in the same setup without the use of any guide bushing, as the tap will follow the drilled hole.

NO.	REQ.	DESCRIPTION	MATERIAL	SIZE
1	1	BODY	CAST IRON	PATT. No. 709 T.R.
2	1	CARB. HDN. & GRD.	MACH. ST.	4 DIA. x $6\frac{7}{8}$
3	1	BUSHING PLATE	MACH. ST.	$\frac{7}{8}$ x $4\frac{1}{8}$ x $5\frac{1}{2}$
4	1	C-WASHER	MACH. ST.	$2\frac{3}{8}$ DIA. x $\frac{3}{4}$
5	1	HEX. NUT ST'D. & WASHER C.R.ST.		$\frac{3}{4}$ - 10 NUT
6	1	HANDLE	C.R.ST.	$\frac{1}{4}$ x $\frac{3}{4}$ x $4\frac{5}{8}$
7	2	STOP	C.R.ST.	$\frac{1}{4}$ DIA. x $1\frac{1}{2}$
8	1	SLIP DR. BUSHING	XLO, ST'D. #2 S-13	$\frac{21}{64}$ DRILL x $1\frac{3}{4}$
9	2	LINER BUSHING	XLO, ST'D. #L-43	$\frac{3}{4}$ I. DIA. x 1-O. DIA. x $\frac{3}{4}$
10	1	LOCATOR PIN	ST'D.	$\frac{15}{32}$ DIA.
11	3	REST BUTTON	ST'D.	
12	3	HEX. HD. CAP SCREW	ST'D.	$\frac{1}{2}$-13 x $1\frac{3}{4}$
13	2	DOWEL	ST'D.	$\frac{1}{2}$ DIA. x $1\frac{3}{4}$
14	2	DOWEL	ST'D.	$\frac{3}{8}$ DIA. x $1\frac{1}{2}$
15	4	FIL. HD. SCREW	ST'D.	$\frac{3}{8}$ -16 x 1

Fig. 35C. Bill of Materials for the Design Shown in Fig. 35A

In some designs of jigs it is necessary to grind a flat on one side of the press fit drill bushings in order to permit close center distances, just as it was necessary in Fig. 35A to flatten off the liner bushings.

INDEXING JIGS

The piece part shown in Figs. 36A and 36B is a bevel gear bearing cage cap used on a track-laying type of tractor. For such a work piece an indexing jig is generally designed. It is necessary to provide a jig for drilling and reaming the 2.0475″ hole (Fig. 36B), and to drill and tap a ⅛″ pipe-thread hole (section *B-B* of Fig. 36B). There are two of these piece parts used, one right-hand and one left-hand. As they are almost identical except for the location of the bosses mentioned, one jig can be designed to perform these

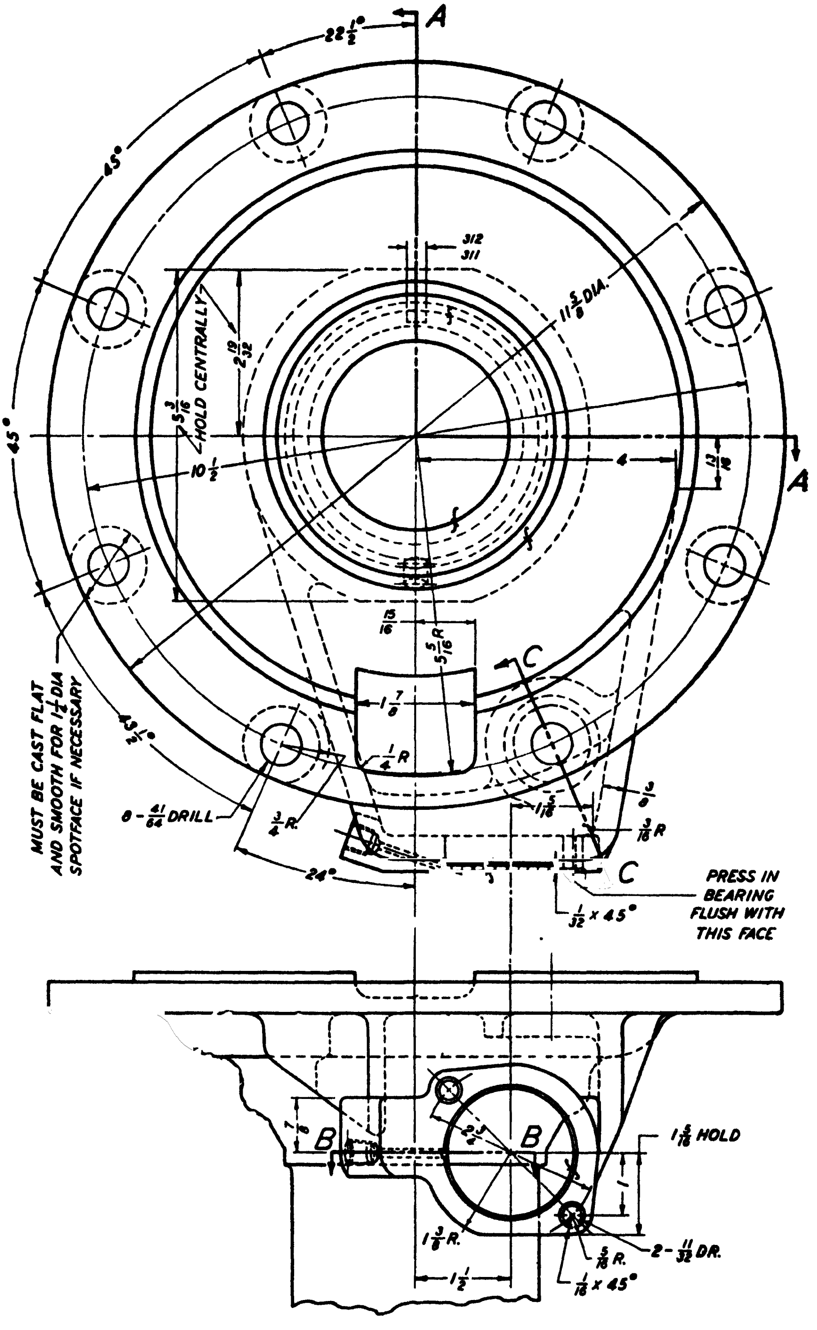


Fig. 36A. Bevel Gear Bearing Cage Cap

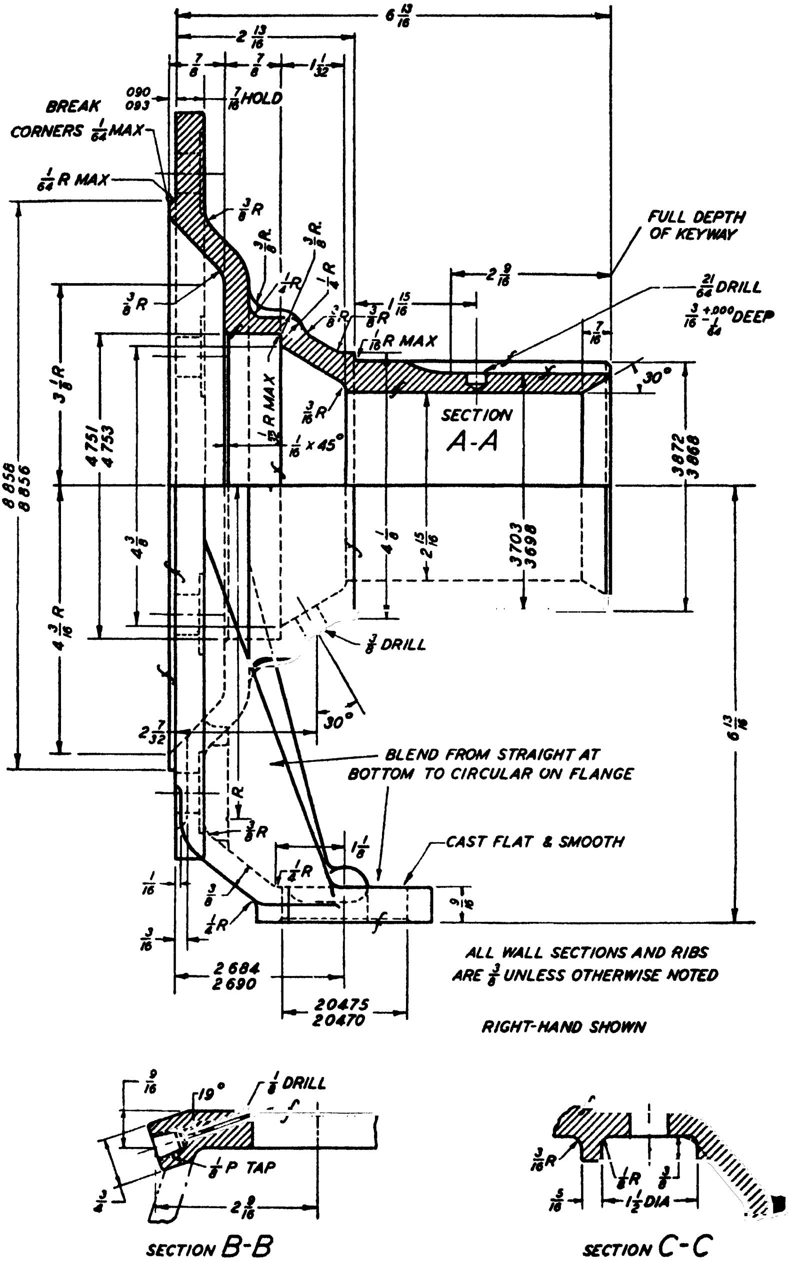
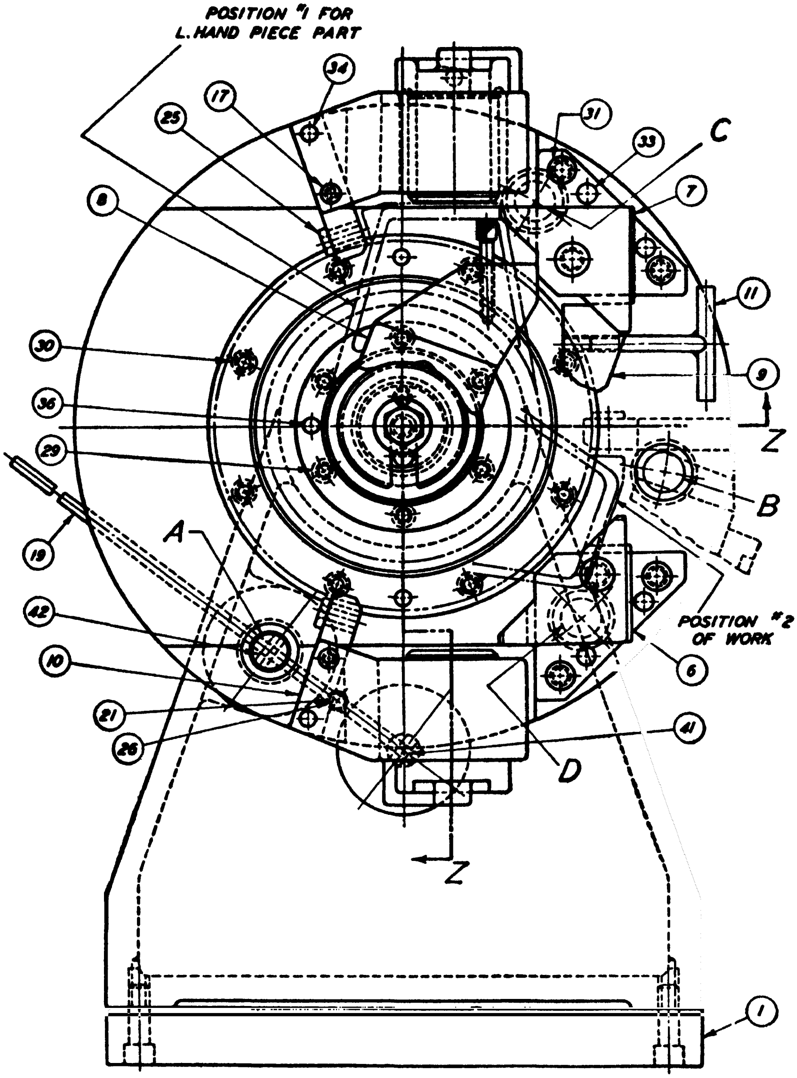


Fig. 36B. Right-Hand View and Sections for the Design Shown in Fig 36A



NOTE:

A INDEXING HOLE FOR 2.0475 HOLE } LEFT HAND PIECE PART
B INDEXING HOLE FOR $\frac{1}{8}$ P. TAP HOLE } LEFT HAND PIECE PART
C INDEXING HOLE FOR 2.0475 HOLE } RIGHT HAND PIECE PART
D INDEXING HOLE FOR $\frac{1}{8}$ P. TAP HOLE } RIGHT HAND PIECE PART

Fig. 37A. This Figure and Fig. 37B Comprise the Assembly Drawing of an Indexing Jig

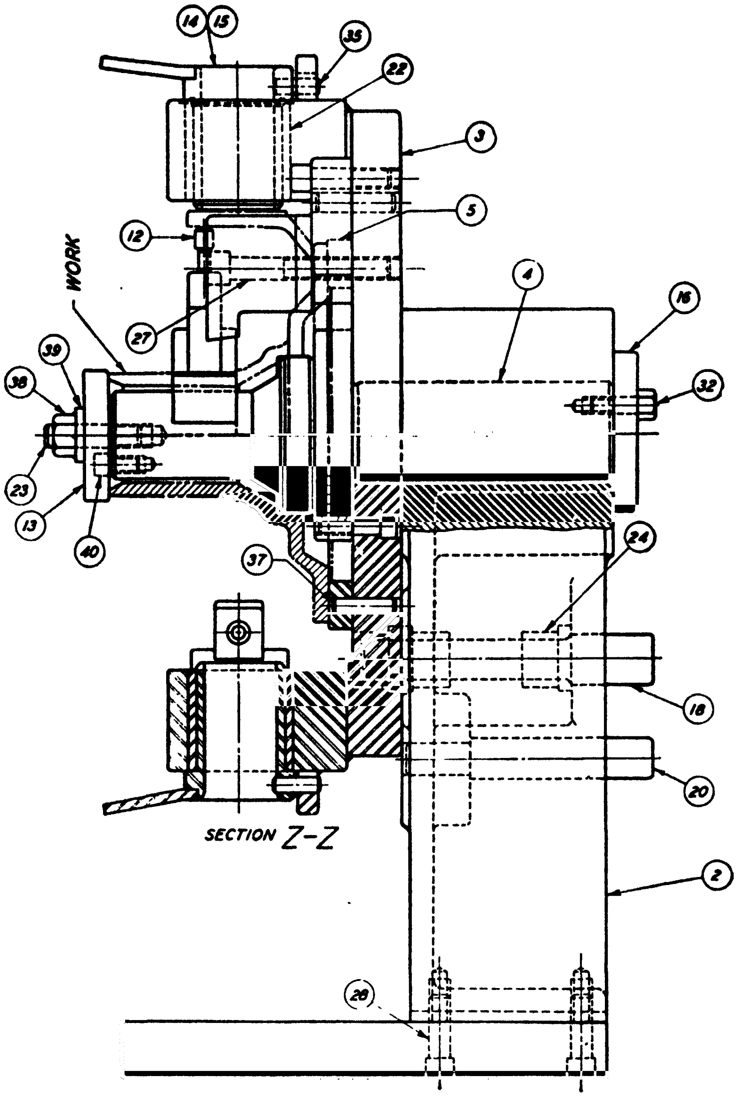


Fig. 37B. View which Completes the Assembly Drawing Shown in Fig. 37A

operations. In the section where the 2.0475″ hole is drilled and reamed, there are two $^{11}/_{32}''$ holes for attaching a cap, or cover, to this particular part; an auxiliary jig must be provided to drill these two $^{11}/_{32}''$ holes after the large hole has been drilled and reamed and the bosses have been spotfaced.

Figs 37A and 37B are an assembly drawing of an indexing jig.

Note that details *24* to *42*, inclusive, listed on the bill of materials, Fig. 37C, are for standard parts for the jig shown on Figs. 37A and 37B. This jig, as you will note from the drawing, has a base plate (*1*) with a stand (*2*). This stand is made of gray iron from a standard pattern. The base is made of machine steel which is machined over the top and bottom to provide a level surface for the stand and for resting this jig on the base of a radial drill press.

No.	NAME	REQ.	MATERIAL	SIZE
44	HOL'S. DR. BUSH.	2	XLO, ST'D.	0-82A-FOR $\frac{11}{32}$ DR. x 1 LG.
43	SOCK. HD. SCR.	4	ST'D.	$\frac{1}{4}$-20 x 1$\frac{1}{4}$ LG.
42	PIN	1	ST'D.	$\frac{3}{8}$ DIA. x 1$\frac{1}{2}$ LG.
41	PIN	1	ST'D.	$\frac{3}{8}$ DIA. x 1$\frac{1}{4}$ LG.
40	SOCK. HD. SCR.	1	ST'D.	$\frac{1}{2}$-13 x 1 LG.
39	WASHER	1	ST'D.	FOR $\frac{3}{4}$ STUD
38	HEX. NUT	1	ST'D.	$\frac{3}{4}$-10 NUT
37	DOWEL	2	ST'D.	$\frac{3}{8}$ DIA. x 2 LG.
36	DOWEL	1	ST'D.	$\frac{1}{2}$ DIA. x 2$\frac{1}{2}$ LG.
35	DOWEL	1	ST'D.	$\frac{1}{2}$ DIA. x 1$\frac{1}{2}$ LG.
34	DOWEL	2	ST'D.	$\frac{1}{2}$ DIA. x 3 LG.
33	DOWEL	4	ST'D.	$\frac{5}{8}$ DIA x 2$\frac{1}{2}$ LG.
32	HEX. HD SCR.	3	ST'D.	$\frac{1}{2}$-13 x 1$\frac{1}{2}$ LG.
31	SOCK. HD SCR.	4	ST'D.	$\frac{5}{8}$-11 x 2$\frac{1}{2}$ LG.
30	SOCK. HD. SCR.	8	ST'D.	$\frac{1}{2}$-13 x 2 LG.
29	SOCK. HD. SCR.	6	ST'D.	$\frac{1}{2}$-13 x 2 LG.
28	SOCK. HD SCR.	4	ST'D.	$\frac{5}{8}$-11 x 2 LG.
27	SOCK. HD SCR.	2	ST'D.	$\frac{3}{4}$-10 x 5 LG.
26	SPRING	1	SPRING ST.	TO SUIT
25	BUSHING, XLO	2	ST'D.	0-62A-$\frac{11}{32}$ DRILL x 1 LG.
24	BUSHING, XLO	15	ST'D.	X-66-1.250 HOLE x 1 LG.

Fig. 37C. Bill of Materials for Standard Parts for the Jig Shown in Figs. 37A and 37B

There are four index holes provided in this jig (labeled *A*, *B*, *C*, and *D*) and the jig is designed so that both right-hand and left-hand piece parts can be drilled in it. This type of jig illustrates some of the principles that have been covered in the preceding pages. The details will be discussed and illustrated by Figs. 38 to 42 inclusive.

Fig. 38 is a detail drawing of a stand or, as it is sometimes termed, trunnion bracket. It is shown on Fig. 37B as detail (*2*). This particular design happens to be a company standard and can be used for other jobs where a stand of this size is needed. In some instances where these stands are used for indexing jigs of the trunnion type, two stands would be mounted on a base.

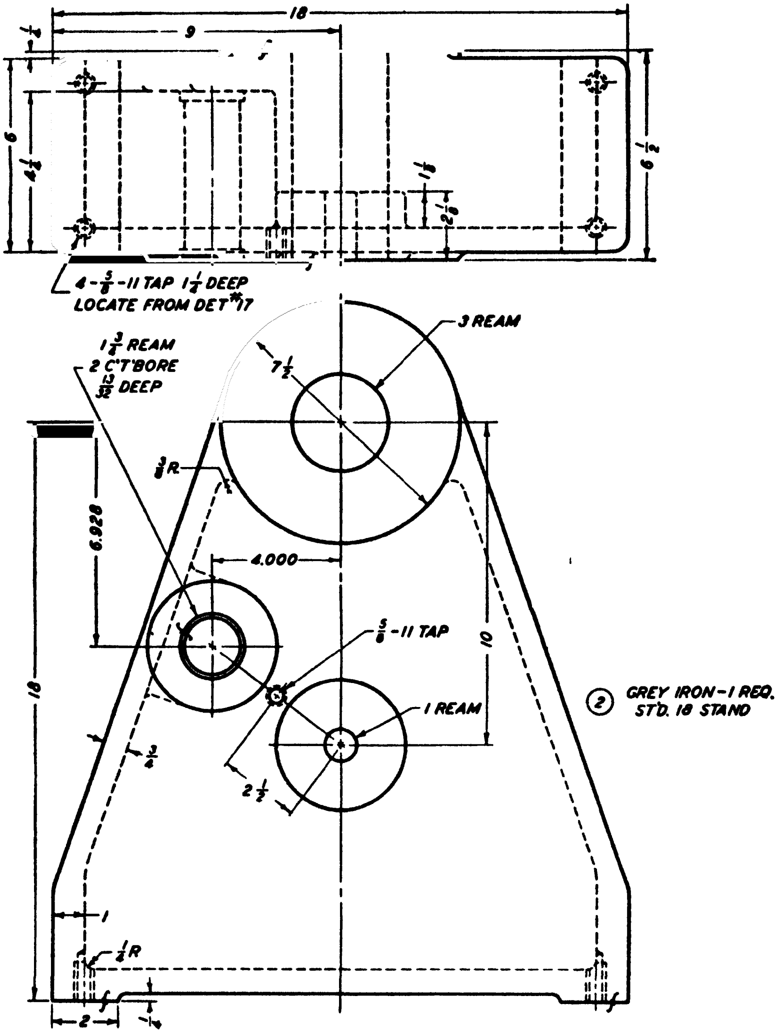


Fig. 38. Detailed Drawing of the Stand Shown as Detail 2 of Fig. 37B

Fig. 39A is a front elevation and plan view of the body for the jig shown in Figs. 37A and 37B, and the right side elevation is shown in Fig. 39B. It is made of machine steel and is of welded construction. There are four 1¾″ index holes that are located in

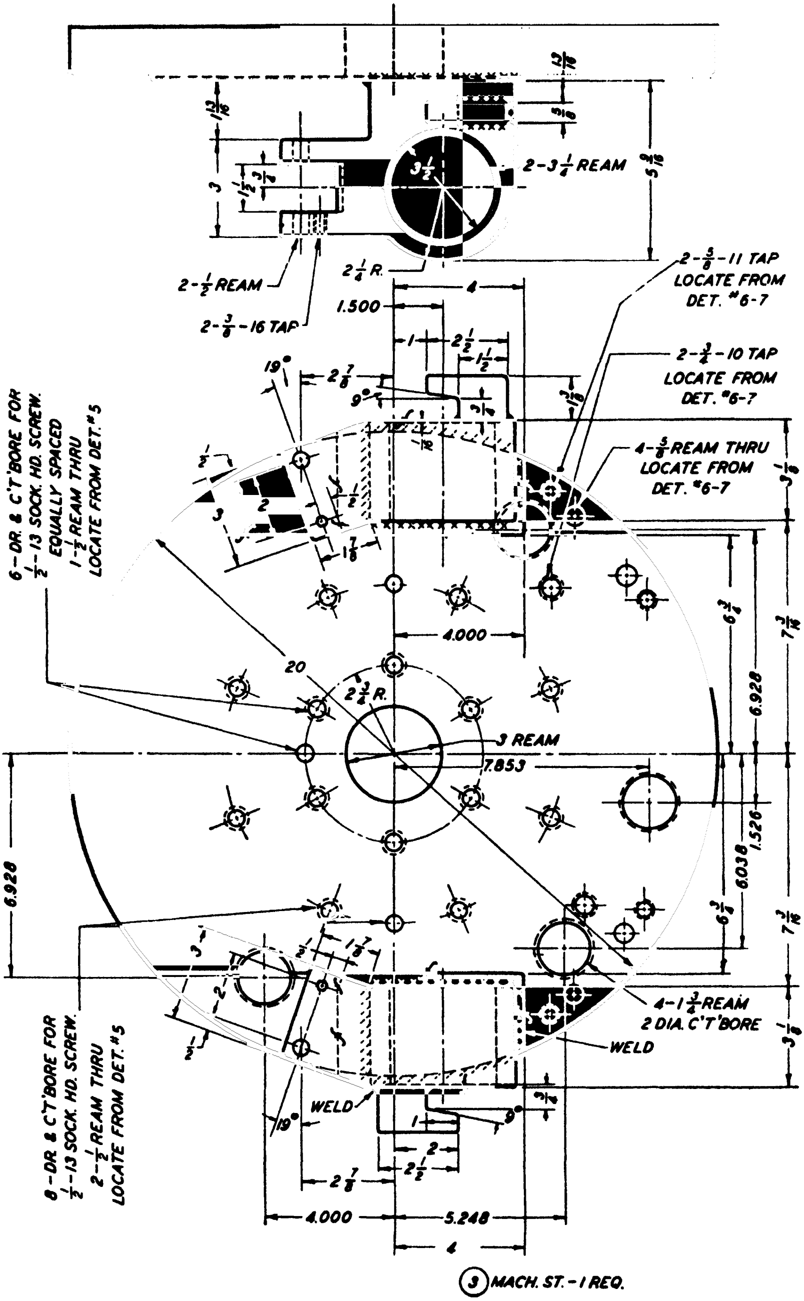

2-3 1/4 REAM
5 9/16
13/16
5/16
1 13/16
3
1 1/2
3/4
3 1/2
2 1/4 R.
2-1/2 REAM
2-3/8-16 TAP
1.500
4
1
2 1/2
1 1/2
2 7/8
19°
9°
3/16
2-5/8-11 TAP LOCATE FROM DET. #6-7
2-3/4-10 TAP LOCATE FROM DET. #6-7
4-5/8 REAM THRU LOCATE FROM DET. #6-7
3 1/8
6-DR. & C'T'BORE FOR 1/2-13 SOCK. HD. SCREW. EQUALLY SPACED 1-1/2 REAM THRU LOCATE FROM DET. #5
4.000
20
2 3/4 R.
3 REAM
7.853
6 1/4
7 3/16
6.928
6.038
1.526
1 7/8
4-1 3/4 REAM 2 DIA. C'T'BORE
WELD
8-DR. & C'T'BORE FOR 1/2-13 SOCK. HD. SCREW. 2-1/2 REAM THRU LOCATE FROM DET. #5
2 1/2
2
4.000
5.248
3 MACH. ST. - 1 REQ.

Fig. 39A. Front Elevation and Plan View of the Body for the Jig Shown in Figs. 37A and 37B

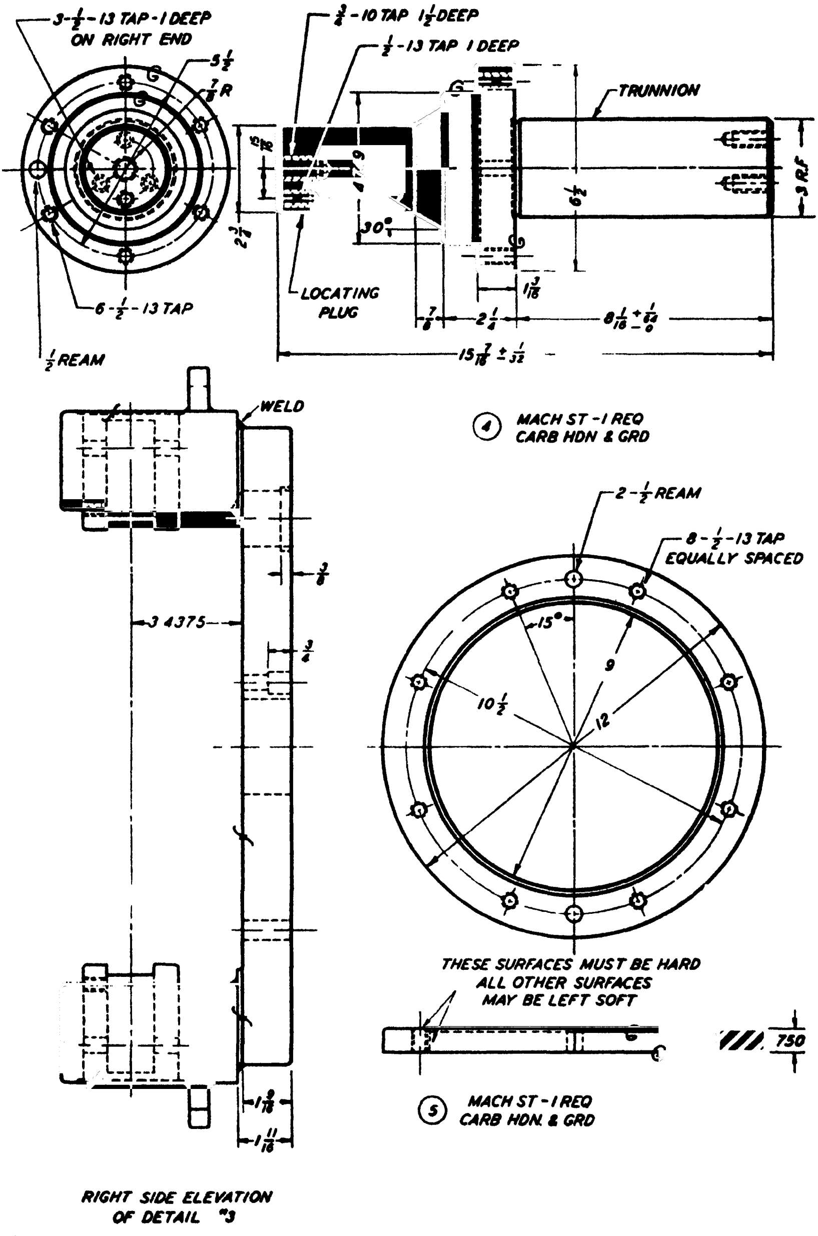

3-1/2-13 TAP-1 DEEP ON RIGHT END
5 1/2
7/8 R
6-1/2-13 TAP
1/2 REAM
3/4-10 TAP 1 1/2 DEEP
1/2-13 TAP 1 DEEP
TRUNNION
15/16
2 3/4
4 1/2 9
30°
6 1/2
3 R.F.
LOCATING PLUG
1 3/16
7/8
2 1/4
8 1/16 +1/64 -0
15 7/16 ± 1/32
WELD
④ MACH ST - 1 REQ CARB HDN & GRD
2-1/2 REAM
8-1/2-13 TAP EQUALLY SPACED
3/8
3.4375
3/4
15°
9
10 1/2
12
THESE SURFACES MUST BE HARD ALL OTHER SURFACES MAY BE LEFT SOFT
.750
1 9/16
1 11/16
⑤ MACH ST - 1 REQ CARB HDN & GRD
RIGHT SIDE ELEVATION OF DETAIL #3

Fig. 39B. Details and Right Side Elevation of Jig Body for the Jig Shown in Figs. 37A and 37B

definite relation to the holes that are to be drilled in the piece part. These holes are carefully bored for the insertion of hardened and ground shoulder-type drill bushings (*24* of Fig. 37B) so that no excessive wear will be caused by the index pin. As stated, this jig is designed to accommodate both right-hand and left-hand piece parts; therefore the jig must be capable of locating both parts in definite relation to previously machined dimensions. The jig body is detail *3*. Also shown on Fig 39B are details *4* and *5*. Detail *4* is the locating plug and trunnion about which the jig body revolves. A hardened and ground ring (detail *5*) is mounted on the face of the jig body, see Fig. 37B, to act as a rest and locating pad. This prevents wear that would be caused by putting in and taking out the piece parts.

Fig. 40 shows the design and construction of the locating blocks, details *6* and *7*. These are designed to be made of machine steel of welded construction, carburized, hardened and ground to prevent wear. By referring to Fig. 37A the location of these blocks can readily be determined. Fig. 40 also shows details *8* and *9*.

Fig. 41 shows the design of details *1*, and *10* to *17* of this jig and Fig. 42 is a drawing showing the design of details *18* to *23*.

To drill the two $^{11}/_{32}''$ holes that are on the boss of this piece part where the 2.0475″ hole is drilled and reamed, an auxiliary jig, Fig. 43, is designed. This is an assembly drawing and illustrates the general design of this type of jig. Fig. 44 illustrates the details. Detail *45* is the bushing plate which is designed to be made out of machine steel, carburized, hardened, and ground at the necessary points (indicated by the letter *G*). Details *48* and *49* are the jaws that are actuated by a right-hand and left-hand thread shown on screw, detail *46*. The screw actuates the jaws so that they will locate in the 2.0475″ hole. These jaws are somewhat similar to the clamps on a pair of roller skates; that is, they operate simultaneously by rotating the screw in one way, either to the right or left. This causes these jaws to open or close as may be desired. This is a simple method of clamping an auxiliary jig to perform additional operations on a piece part. By referring again to Fig. 43 you will note the assembly of these jaws on the bushing plate.

When it is necessary to drill a part similar to Fig. 45, which is a front axle center for a tractor, the tool designer must give careful

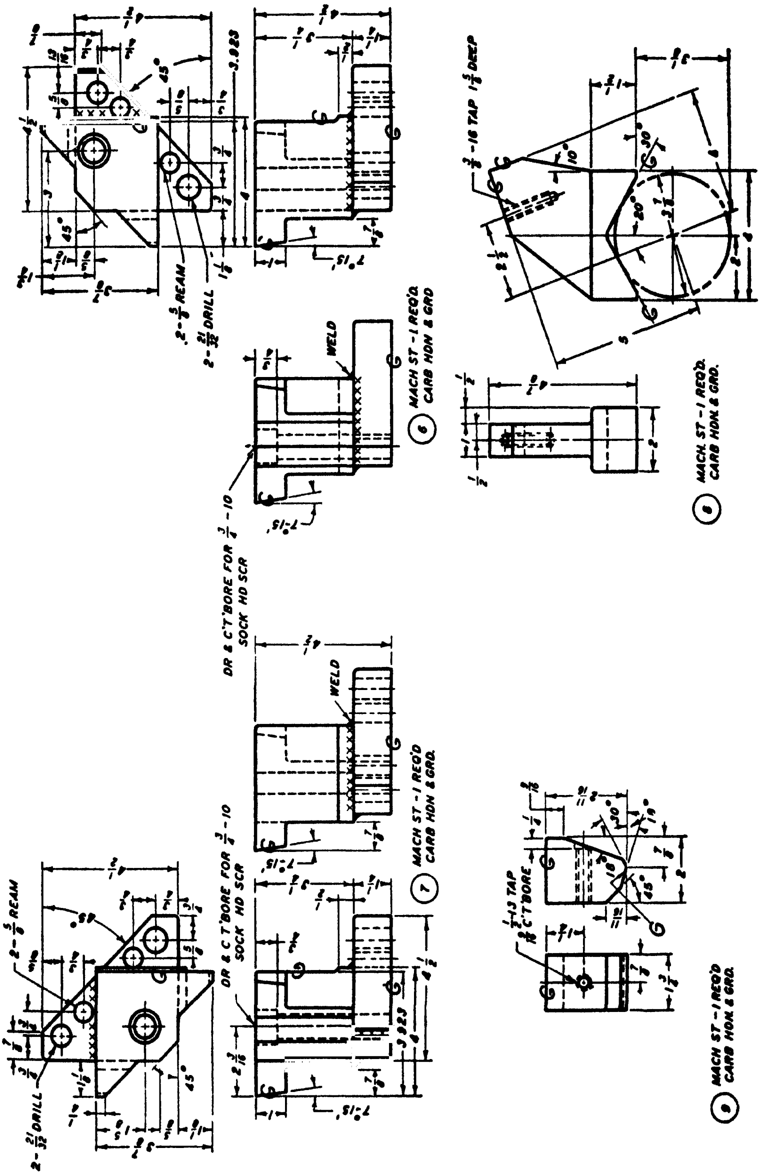

2-5/8 REAM
2-21/32 DRILL
45°
3.923
DR & C'T'BORE FOR 3/4-10 SOCK HD SCR
WELD
7-15°
⑥ MACH ST - 1 REQ'D CARB HDN & GRD
⑦ MACH ST - 1 REQ'D CARB HDN & GRD
3/8-16 TAP 1 5/8 DEEP
30°
10°
20°
⑧ MACH. ST. - 1 REQ'D. CARB HDN & GRD.
1/4-13 TAP 3/8 C'T'BORE
18°
45°
⑨ MACH ST - 1 REQ'D CARB HDN & GRD.

Fig. 40. Design and Construction of Details for Fig. 37A

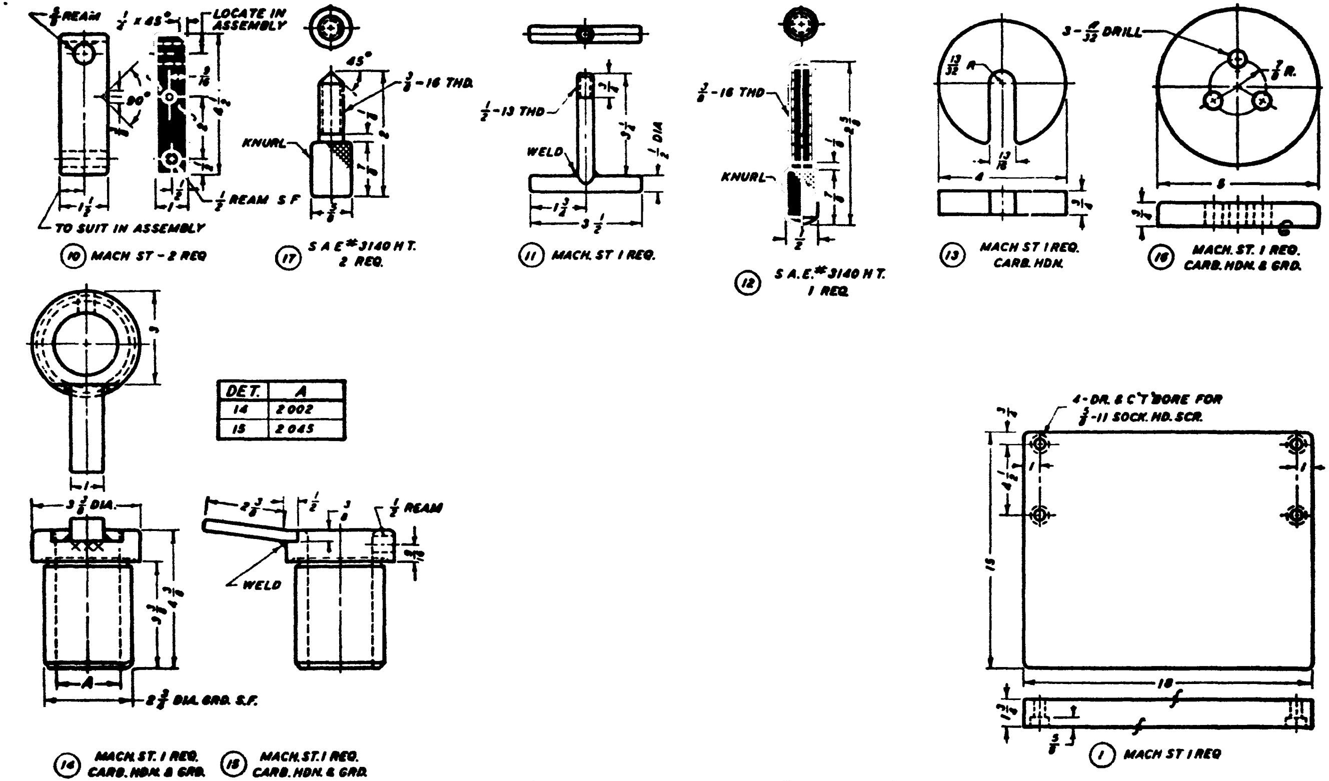


Fig. 41. Design of Details of Jig Shown in Figs. 37A and 37B

consideration to the type of jig he will design, as well as the method of locating this piece part in the jig. The piece part is large, the over-all length being 34½″. This eliminates the possibility of doing the drilling in a box jig as it would be slow; moreover it would require a crane to turn it over. Another design problem is found in

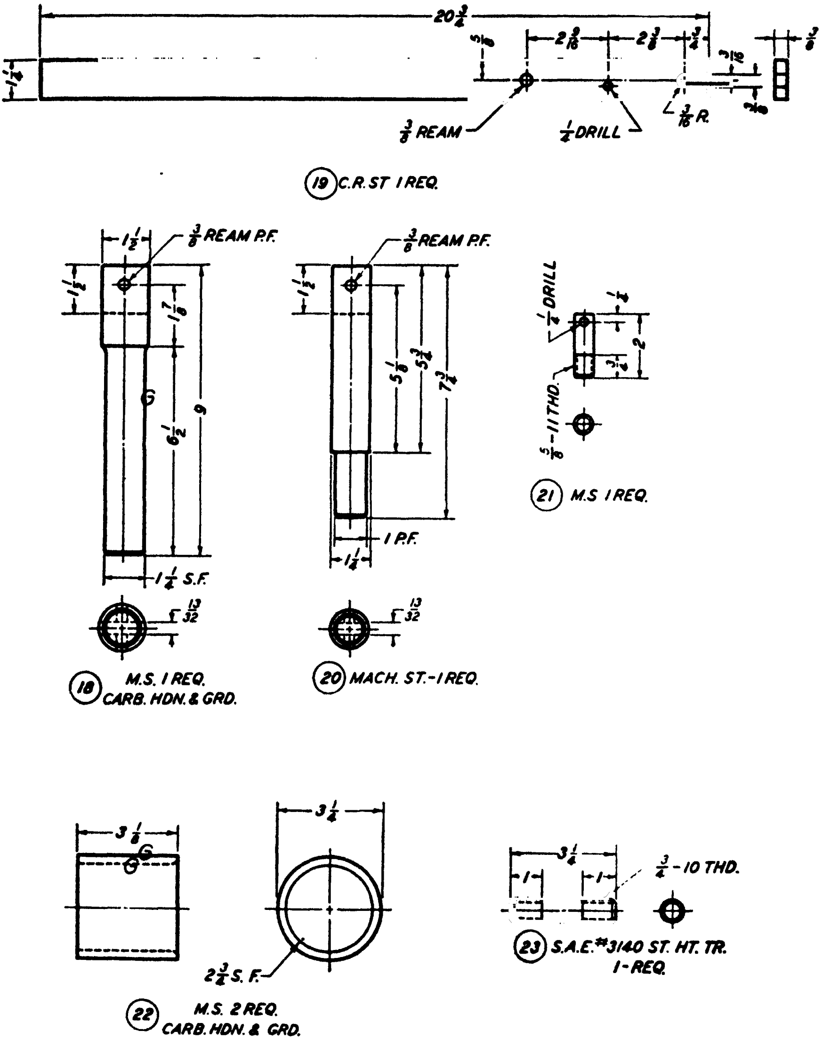


Fig. 42. Design of Details of Jig Shown in Figs. 37A and 37B

the fact that the four $^{57}/_{64}''$ holes are at an angle of 5° below the horizontal center line, while the four $^{21}/_{32}''$ holes are 5° above the

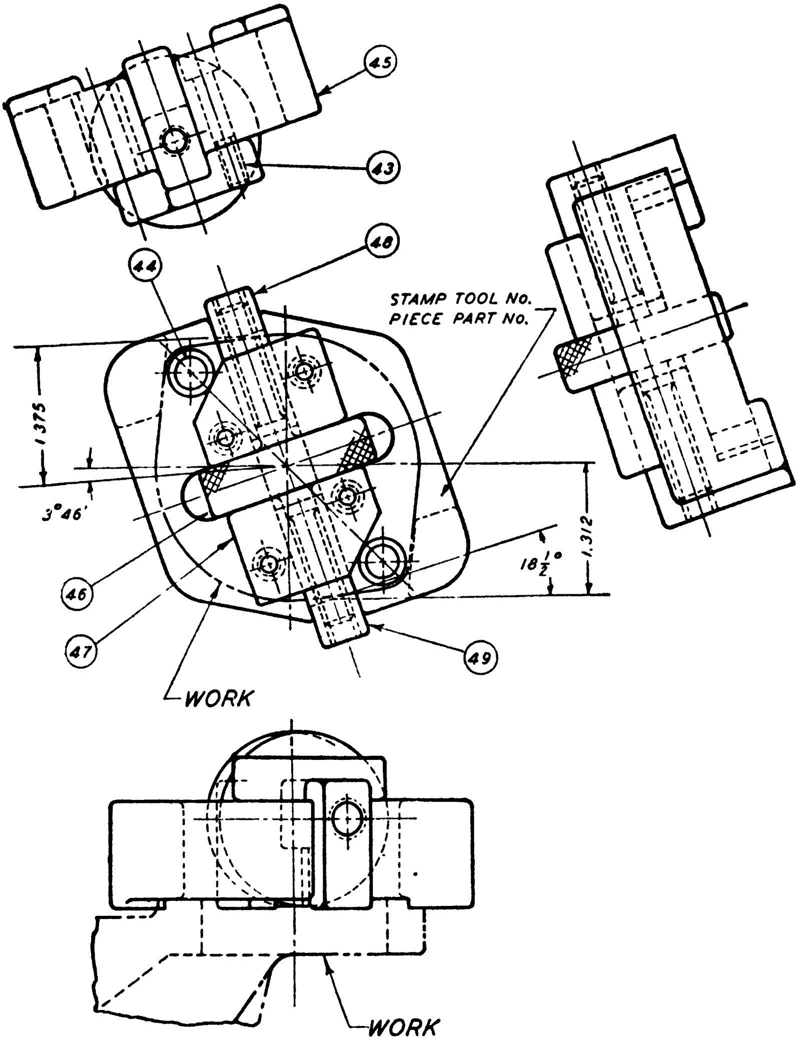


Fig. 43. Assembly Drawing of an Auxiliary Jig for Use on the Piece Part Shown in Figs. 36A and 36B

center line. The piece part is a malleable iron casting and no machining is performed on it before the drilling operation.

The necessary operations include drilling and reaming the

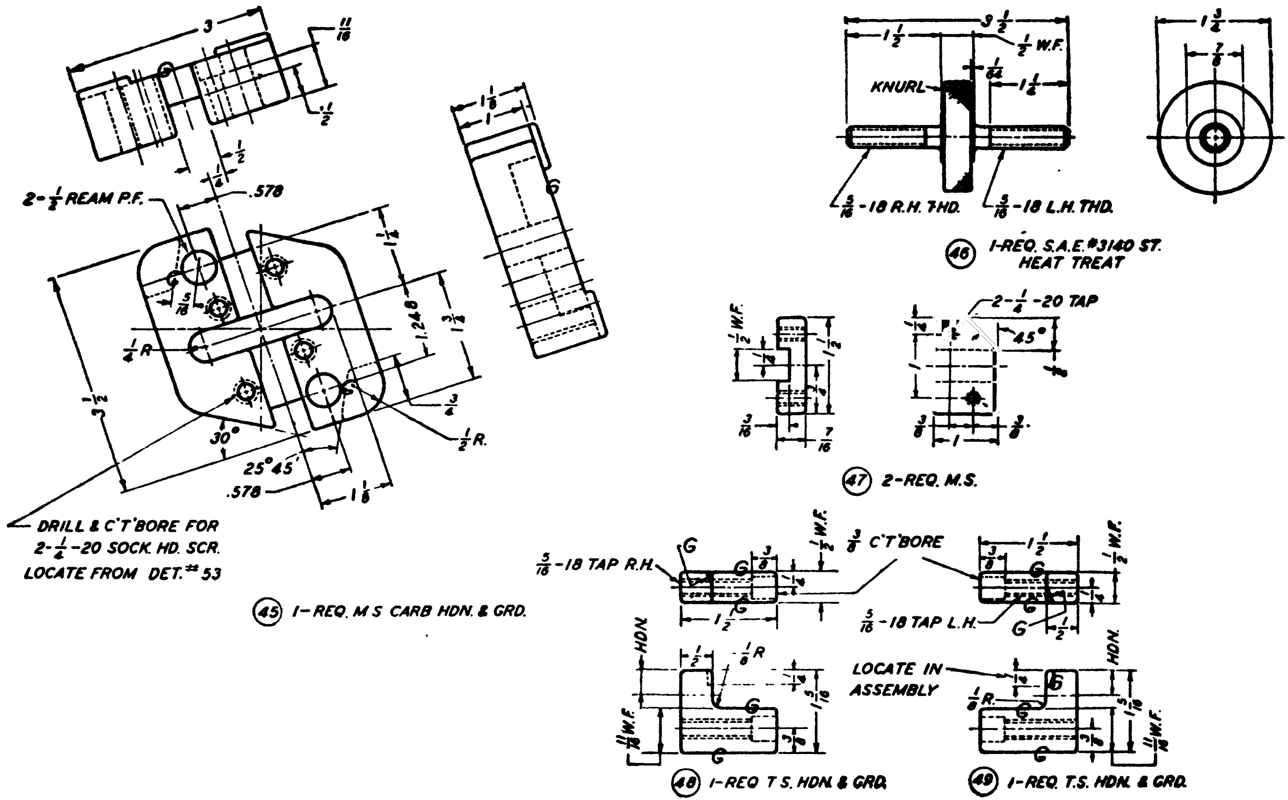


Fig. 44. Details of the Jig Shown in Fig. 43

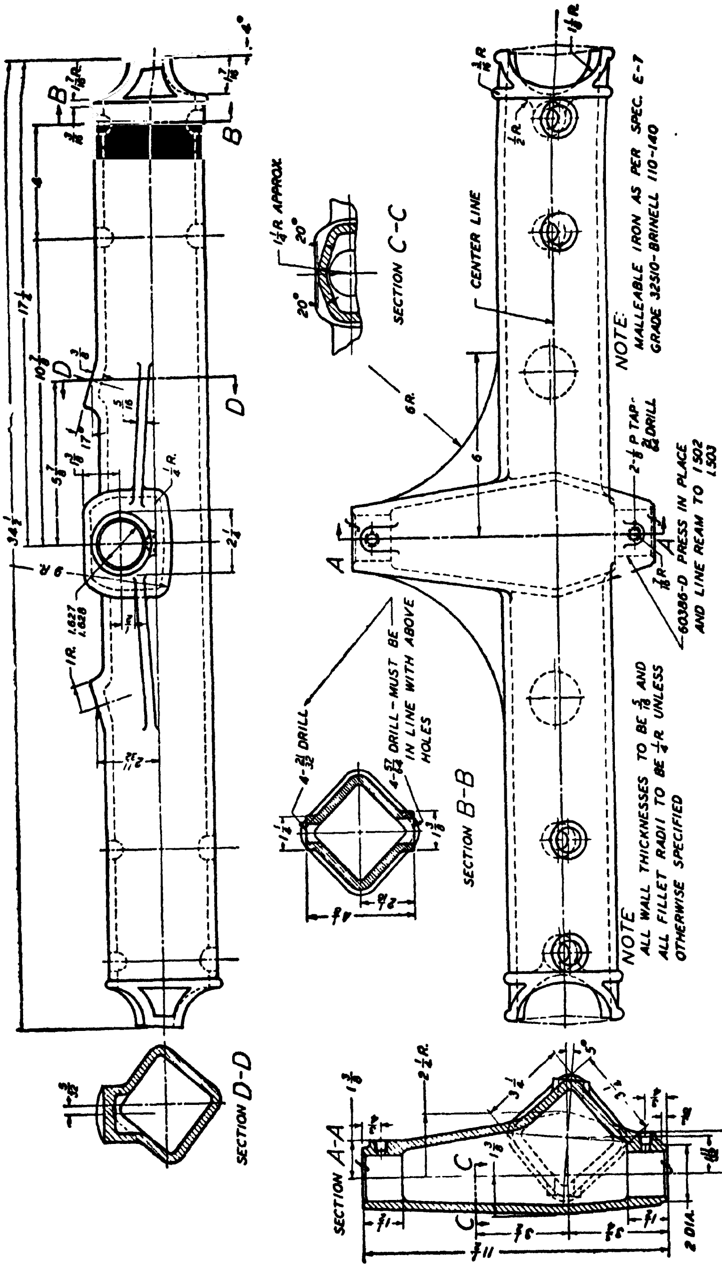


Fig. 45. Front Axle Center for a Tractor

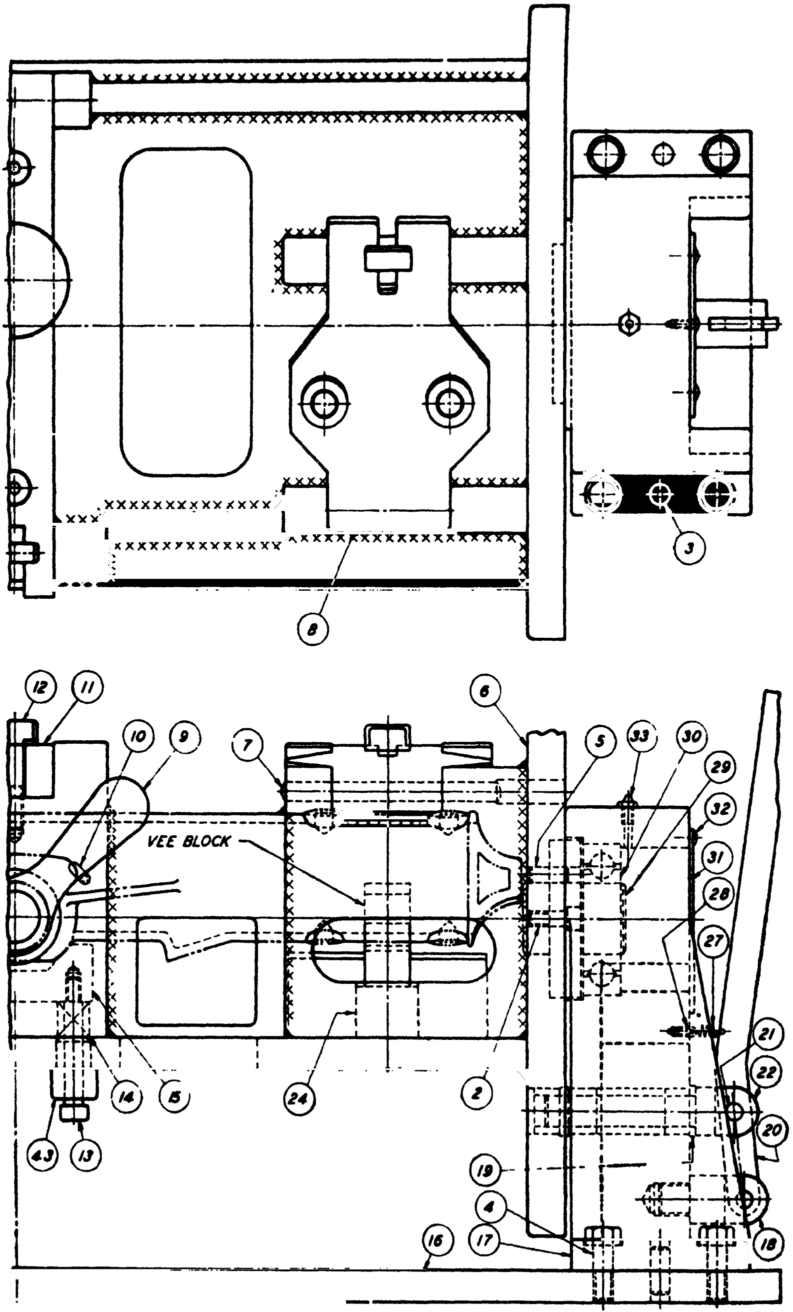
1.627″ to 1.628″ hole, spotfacing the bosses and countersinking both sides, drilling four $^{21}/_{32}$″ holes, drilling four $^{57}/_{64}$″ holes, drilling and tapping two ⅛″ pipe tap holes. Therefore, it was decided to design an indexing drill jig for performing these drilling operations.

Fig. 46A is an assembly drawing showing the right half of a symmetrical trunnion type index drill jig for the piece part shown in Fig. 45. It will be noted in this illustration that the design consists of a base made out of cold-drawn steel (detail *16*) on which are mounted two stands (detail *17*) one on each end. It is necessary to have an indexing pin (*22*) and lever (*20*) on each end, because of the fact that the holes in this piece part are on different planes. It would be impossible to accomplish the angular drilling with index holes on only one end of the jig. Also, due to the design of the piece part, two swinging bushing plates (*8*) and one of detail *11* are necessary to provide for the rapid loading and unloading of the piece parts. Drilling operations will be performed in a radial drill press because of the various locations of the holes in the work piece. Fig. 46B gives a view of the plate and a bill of materials.

The jig body, Fig. 47, is designed to be made of welded steel construction. This provides a comparatively light and strong structure for holding the piece part. After the various sections have been located in the proper position, they are welded together, providing a very rigid jig body. After normalizing, the jig body is machined to the required dimensions.

There are four positions in the index plate. The details of the locating means are shown on Fig. 48. Detail *8* illustrates the design of the two bushing plates required for either end of this jig, and detail *11* is a bushing plate made of welded construction for locating the ⅛″ pipe-tap drill. Due to the design of the piece part it is necessary to have an extension welded on to this bushing plate in order to locate the drill bushings (*40*) as close to the work as possible. Detail *24* shows the design of two **V**-blocks to locate the piece part in the required position. It will be noted that this 90° vee is located 5° off the vertical center line of the block in order to position the piece part properly in the jig body. The other details shown in Fig. 48 are similar to those that have been described for other jigs.

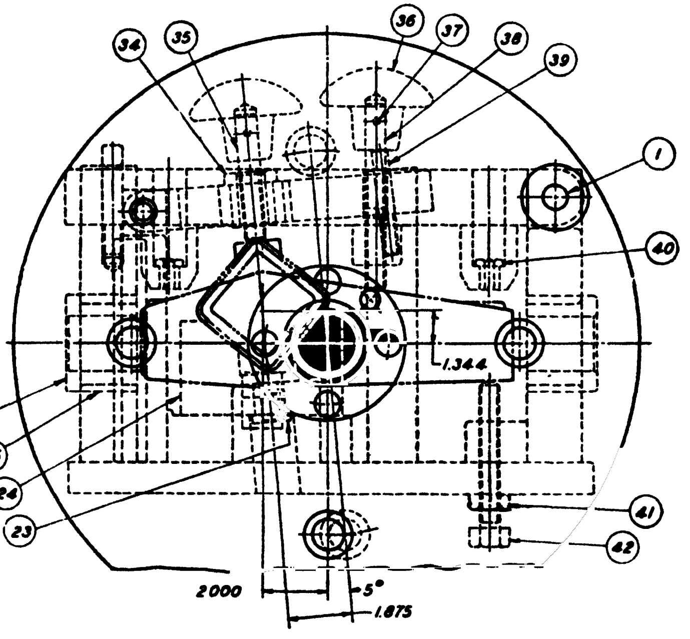
Fig. 49 illustrates the design of the stand (detail *17*). Two are used in conjunction with this type of jig. Detail *29* gives details of



NOTE: JIG IS SYMMETRICAL - ONLY RIGHT HALF SHOWN

Fig. 46A. Assembly Drawing Showing the Right Half of a Symmetrical Trunnion Type Indexing Drill Jig for the Piece Part Shown in Fig. 45

No.	REQ.	DESCRIPTION	MATERIAL	SIZE
42	1	HEX. HD. BOLT	ST'D.	5/8-11 x 4 1/2
41	1	HEX. NUT	ST'D.	5/8-11
40	2	21/64 DRILL BUSHING	XLO, ST'D.	L-62-A
39	2	T SCREW	MACH. ST.	J.S.-111
38	1	KNOB SCREW	M.D.-3140	J.S.-313
37	3	PIN	C.R.ST.	1/8 DIA. x 1 1/2
36	3	HAND KNOB	G.I.	J.S.-288
35	2	KNOB SCREW	M.D.-3140	J.S.-309
34	4	37/64 DRILL BUSHING	XLO, ST'D.	O-65
33	2	ZERK FITTING	ST'D.	1/4-20
32	6	RD. HD. SCREW	ST'D.	1/4-20 x 3/8
30	2	BALL BEARING	ST'D.	ST-221
27	2	SPRING	SPR. ST.	TO SUIT
23	4	21/32 DRILL BUSHING	XLO, ST D.	L-64
21	4	DOWEL	ST'D.	1/2 DIA. x 1 1/2
19	9	BUSHING	T.S.	ED-6540 #2
17	2	STAND	G.I.	USE PATT. I ED-#7190
16	1	BASE	C.D.ST.	1 x 8 x 51 5/8
14	2	SPRING	SPR. ST.	TO SUIT
13	2	STRIPPER BOLT	ST'D.	1/2 DIA. x 3 1/4
12	1	T SCREW	ST'D.	J.S.-112
9	2	HANDLE	MACH. ST.	ED-7002 #3
7	2	LINER PIN	DR. ROD	5/8 DIA x 7
5	2	DOWEL	C.R.ST.	1/2 DIA. x 1 1/4
4	8	HEX. HD. SCREW	ST'D.	5/8-11 x 1 3/4
3	4	DOWEL	ST'D.	5/8 DIA x 1 1/2
2	8	SOCK. HD. SCREW	ST'D.	1/2-13 x 1 1/2
1	1	LINER PIN	DR. ROD.	1/2 DIA x 5



END VIEW OF JIG

Fig. 46B. End View of Jig Shown in Fig. 46A, Together with the Bill of Materials

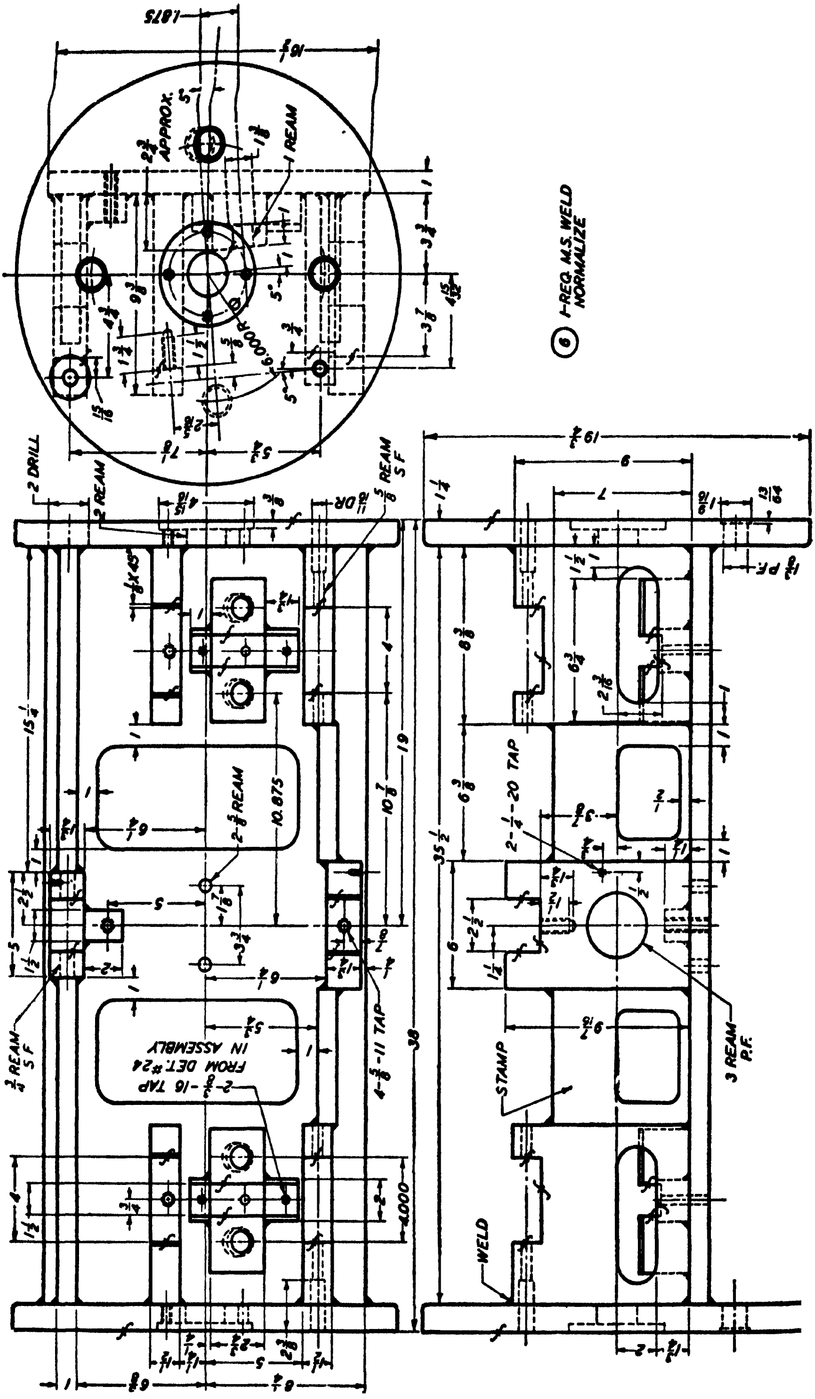


Fig. 47. Design of Body for the Jig Shown in Fig. 46A

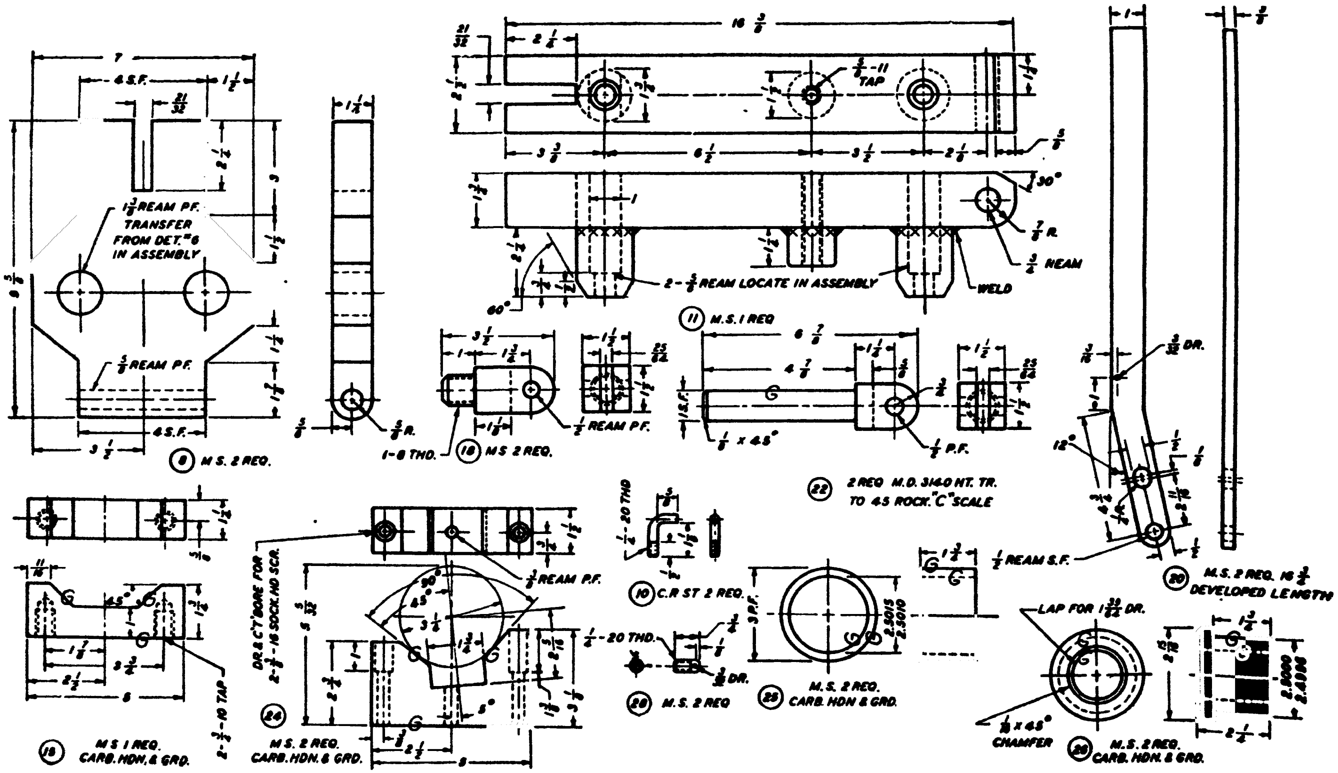

1⅜ REAM P.F. TRANSFER FROM DET. #6 IN ASSEMBLY
⅝ REAM P.F.
4 S.F.
⑧ M.S. 2 REQ.
⅝ R.
1-8 THD.
⑱ M.S. 2 REQ.
½ REAM P.F.
⅝-11 TAP
2-⅝ REAM LOCATE IN ASSEMBLY
WELD
¾ REAM
⅞ R.
⑪ M.S. 1 REQ
⅛ x 45°
½ P.F.
㉒ 2 REQ M.O. 3140 HT. TR. TO 45 ROCK. "C" SCALE
3/32 DR.
½ REAM S.F.
⑳ M.S. 2 REQ. 16⅜ DEVELOPED LENGTH
2-⅜-10 TAP
⑲ M.S. 1 REQ. CARB. HDN. & GRD.
DR. & C'T'BORE FOR 2-⅜-16 SOCK. HD. SCR.
⅜ REAM P.F.
㉔ M.S. 2 REQ. CARB. HDN. & GRD.
¼-20 THD.
⑩ C.R. ST 2 REQ.
¼-20 THD.
⅛ DR.
㉘ M.S. 2 REQ
3 P.F.
2.5015
2.5010
㉕ M.S. 2 REQ. CARB. HDN. & GRD.
LAP FOR 1 33/64 DR.
1/16 x 45° CHAMFER
㉖ M.S. 2 REQ. CARB. HDN. & GRD.
2.5000
2.4996

Fig. 48. Details of the Locating Means for the Jig Shown in Fig. 46A

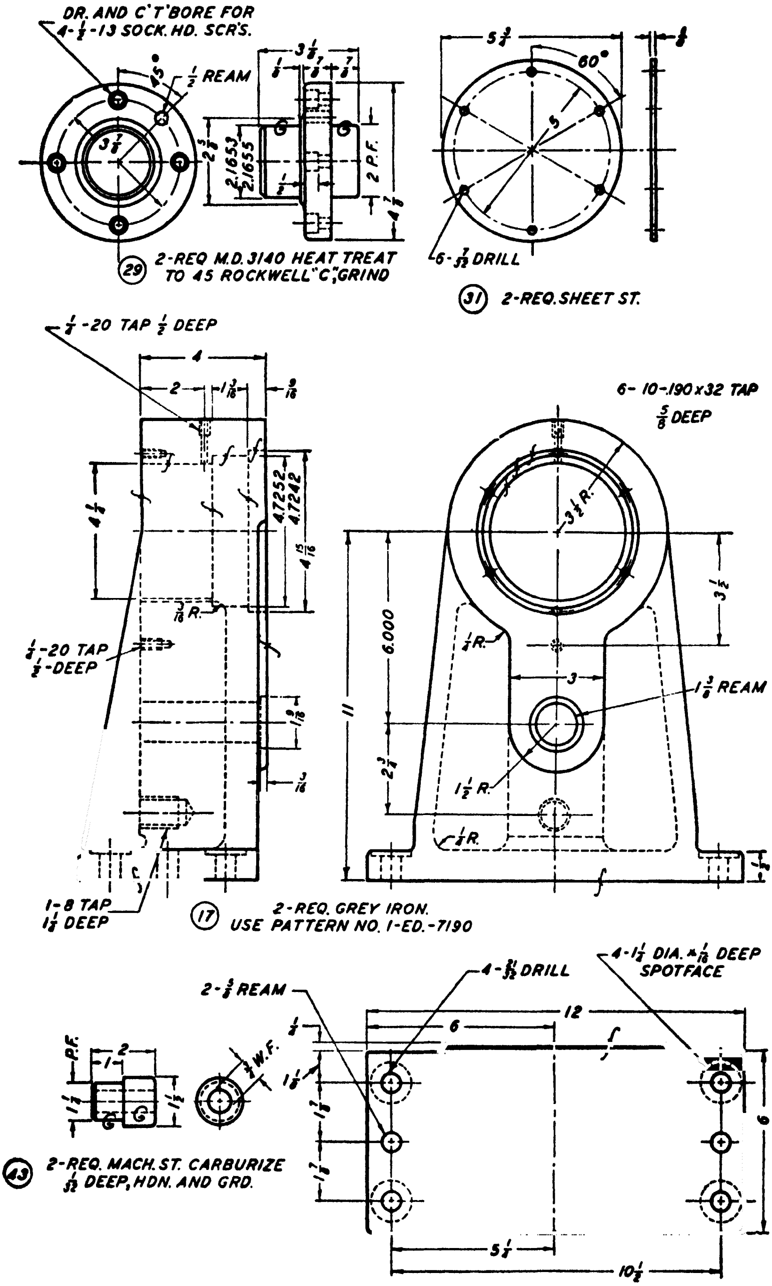


Fig. 49. Design of the Stand Used with the Jig Shown in Fig. 46A

the trunnions that are mounted on either side of the jig body (detail *6*, Fig. 47).

By referring again to Fig. 46A it will be noted that the trunnions have ball bearings (*30*) mounted on them to reduce friction. This permits the jig body to be revolved easily to the proper positions Fig. 46B shows an ordinary hexagon head bolt (*42*) and nut (*41*) mounted in the jig body as an adjustable stop and as a rest for

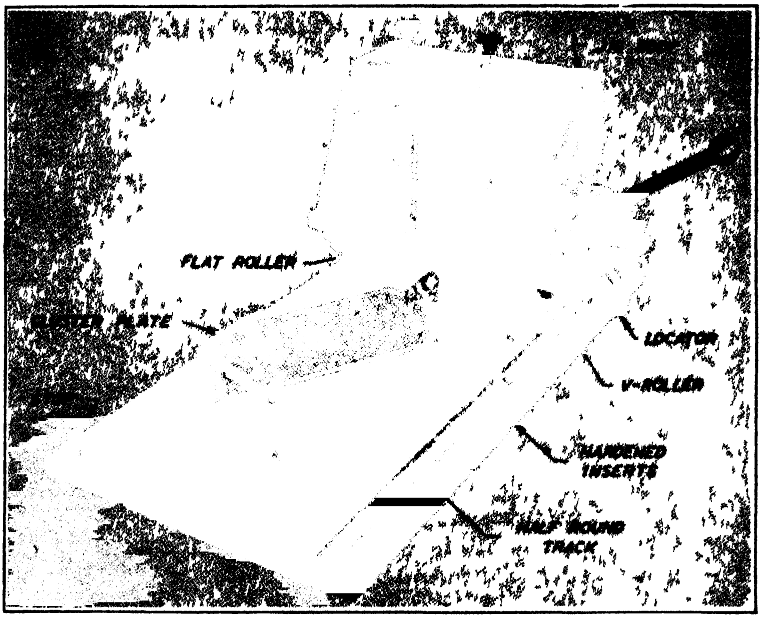


Fig. 50. Indexing Drill Jig with Roller Base and Track

the piece part. The piece part is clamped in the jig by means of screws (*38*) which have hand knobs (*36*) fastened on them by means of pins (*37*).

Fig. 50 illustrates an indexing drill jig designed to be used under a multiple spindle drill. In the immediate foreground is shown a cluster plate that is to be attached to the drill press to locate the drills in proper position. Due to the size of this jig and the work it is to do, rollers are mounted on the jig base in order to move it from one position to another. In addition to indexing the jig body, the entire jig must be definitely located in different positions; for this, hardened and ground inserts are provided in the base of the track on which the jig travels, so that the operator can bring the entire jig in the correct position for the drilling operation.

In this chapter the fundamental principles of jig design have been thoroughly explained and various types of jigs have been illustrated and described. There are other types in constant use in certain kinds of manufacturing plants, but their use is not general enough to warrant description in a book of this size. The tool designer will find that in certain industries devoted to the manufacture of items from metal, definite types of jigs are designed and built. Most other types of jigs can be designed by observing the details of design and construction supplied for those that have been illustrated and described in this chapter.

QUIZ QUESTIONS

1. Define and explain the work of a drill jig.
2. When designing drill jigs, what are some of the important points to be remembered?
3. What are some of the special features of the drill jig shown in Fig. 3?
4. Name some of the advantages in building up angle plate drill jigs by welded construction.
5. What are the special features of the leaf drill jig shown in Figs. 8, 9A, and 9B?
6. What special demands of production are met by the drill jig shown in Fig. 13?
7. What is the special job of the drill jig shown in Figs. 18A and 18B?
8. What special problem is solved in the jig design shown in Fig. 21A?
9. What type of job calls for the use of a cam in the drill jig?
10. In the drill jig illustrated in Fig. 22A, what construction features were introduced to reduce the cost of the jig?
11. What types of work call for the use of swinging clamp drill jigs?
12. When holes must be drilled in two or more sides of a piece part what type of drill jig is generally used?
13. What are some of the special features of construction of the jig body shown in Fig. 32?
14. In the indexing jig shown in Figs. 37A and 37B, how many index holes are provided, and how are the right-hand and left-hand piece parts taken care of?
15. How is the auxiliary jig shown in Figs. 43 and 44 clamped to the job?
16. In the piece part illustrated in Fig. 45, what are some of the special problems that led the designer to decide upon an indexing drill jig for performing the drilling operations?
17. What are some of the special features of the indexing drill jig illustrated in Fig. 50?

FIXTURES

To design the right type of fixtures for performing various machining operations on piece parts, the same principles are used that are used in designing jigs. The words "jig" and "fixture" are used frequently in metal-manufacturing plants. These terms are sometimes confused and as a matter of fact it is difficult to distinguish the difference between these two types of tools. The word "fixture" is frequently misused; for example, on some drawings, a drill jig is called a drill fixture (which in a sense it is) however, the term "fixture" as used in metalworking plants usually denotes a work-holding device that can be used on or in many types of machine tools for producing piece parts to the limits specified on the drawings. Fixtures should be designed so as to hold the work securely while the various machining operations are being performed.

Fixtures are unlike drill jigs in that in most instances they do not have any guide for the cutting tools. This is true except for boring fixtures, which have guide bushings to locate the boring bars properly in the fixtures so that they will operate only where it is desired. The primary purpose of fixtures is to locate and hold the work securely. The accuracy of the work performed is dependent on the type of cutting tools and machine used. Fixtures are designed in a wide variety of types and kinds; the most frequently used is probably the milling fixture, which is used on hand, horizontal and vertical milling machines. A great many fixtures are designed to be used on planer type milling machines, usually for very large work.

There are many types of machining jobs that can be performed in milling machines without the use of fixtures; that is, by clamping the work directly on the milling machine table. However, where quantity production is required, milling fixtures are generally used. On some types of work, even for small quantities, a milling fixture is a decided advantage.

There are certain fundamental principles in fixture design that must be given careful attention by the tool designer. First, the fixture should be designed so as to permit rapid loading and unloading of the work. Second, it should have ample chip clearance. The reason for this is that the accumulation of chips in a fixture prevents the proper locating and holding of the work without considerable cleaning. Third, the fixture should be as strong and rigid as possible without the addition of useless weight. Fourth, the type of fixture should be correct for the machine tool that is to be used in performing the machining operation.

The quantity of pieces to be produced determines the expens that can be allowed for designing and making the fixture. The type of machine to be used also must be considered in the design of the fixture, and the accuracy of the work piece must be carefully studied.

MILLING FIXTURES

In designing milling fixtures it is considered good practice to have the milling fixture as low as possible. In other words, the closer you can bring the work that is located in a fixture on a milling machine table to the table, the less the possibilities of chatter or of springing the work. Milling fixtures are usually provided with keys for locating the fixture properly in the T-slot of the milling machine table. In addition, lugs with slots in them for hold-down bolts must be provided. In some instances an extension of the base of the fixture can be provided for the application of clamps so that the fixture can be properly secured to the milling machine table.

Clamps for milling fixtures should be designed to be as strong as possible and should be provided with springs on the stud so that the clamp itself will spring away from the work when the clamp nut is loosened. The location of clamps on a milling fixture is very important, as the work must be held rigidly in the milling fixture in order to prevent movement. It is necessary that the work piece be located against definite stops. However, there are jobs where, because of the design of the piece part, the work will have to locate against a clamp; this should be avoided if possible.

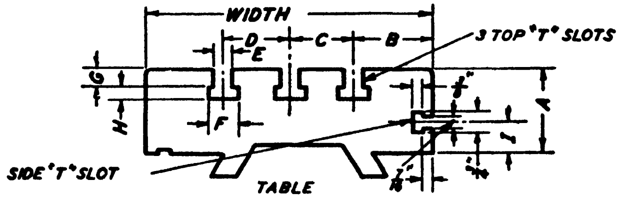
Specifying the right materials for making milling fixtures is very important, and the tool designer must remember that where piece parts are to be loaded and unloaded into a fixture, particularly on high-production quantities, all parts of the fixture that will be subject to wear should be made of material that can be hardened; for example, clamps, rest pins, stops, locating pins, pads, etc.

The design of the fixture should be as simple as possible. The designer should keep in mind that the more parts there are on a fixture, the more possibilities there are for error and trouble. This is true of all types of fixtures. It is sometimes easier to design a very complicated fixture than a simple one; however, the complicated fixture would cause considerable trouble in the shop, whereas a simple fixture will be satisfactory.

Before designing a milling fixture, data should be available as to the dimensions of the milling machine table on which the fixture is to be used; therefore in most plants this information is available in the form of a chart similar to Fig. 1. This chart gives information on four sizes of milling machine tables. It gives the width, the over-all length, the height, the center distance of the T-slots and the number of T-slots. With this information the tool designer can readily determine what type of fixture will be suitable for these machines.

KEARNEY & TRECKER CORPORATION MILLING MACHINES

"T" SLOT SIZES AND LOCATIONS



HORIZONTAL AND VERTICAL MACHINES

TYPE MACH.	WIDTH TABLE	LENGTH TABLE	A	B	C	D	E	F	G	H	I
1	12	44	3.375	$3\frac{1}{4}$	$2\frac{3}{4}$	$2\frac{3}{4}$	$\frac{11}{16}$	$1\frac{3}{16}$	$\frac{3}{4}$	$\frac{1}{2}$	$1\frac{11}{32}$
2	12	56	3.375	$3\frac{1}{4}$	$2\frac{3}{4}$	$2\frac{3}{4}$	$\frac{11}{16}$	$1\frac{3}{16}$	$\frac{3}{4}$	$\frac{1}{2}$	$1\frac{11}{32}$
3	16	64	3.875	$4\frac{1}{2}$	$3\frac{1}{2}$	$3\frac{1}{2}$	$\frac{13}{16}$	$1\frac{7}{16}$	$\frac{7}{8}$	$\frac{5}{8}$	$1\frac{11}{32}$
4	16	80	3.875	$4\frac{1}{2}$	$3\frac{1}{2}$	$3\frac{1}{2}$	$\frac{13}{16}$	$1\frac{7}{16}$	$\frac{7}{8}$	$\frac{5}{8}$	$1\frac{11}{32}$

NOTE: ALL SIZES ARE GIVEN IN INCHES

Fig. 1. Milling Machine Table Chart

Fig. 2 is a data sheet that gives the tool designer complete information on the complete milling machine; for instance, information as to the maximum height to which the fixture can be designed, the width, the amount of horizontal traverse of the table, and the amount of cross feed that is available in the machine. All these factors *must be known to the tool designer* so that he can lay out a milling fixture that will be suitable for the job.

Vises for Milling Machine. The simplest form of milling fixture is a milling machine vise. Fig. 3 illustrates one that is adjustable. In this photograph two vises are mounted on the milling machine table in a vertical milling machine. Two castings are clamped in these vises and machined by means of a face milling cutter of sufficient diameter to machine the entire surface of these castings. In operation, the table is traversed in either direction. When one casting is machined, it is unloaded and a new casting inserted in the vise; and when the second casting has been machined, a new casting is loaded in the second vise and the milling machine table is traversed in the opposite direction. In this way constant production is obtained without any serious interruption. Various types of milling machine

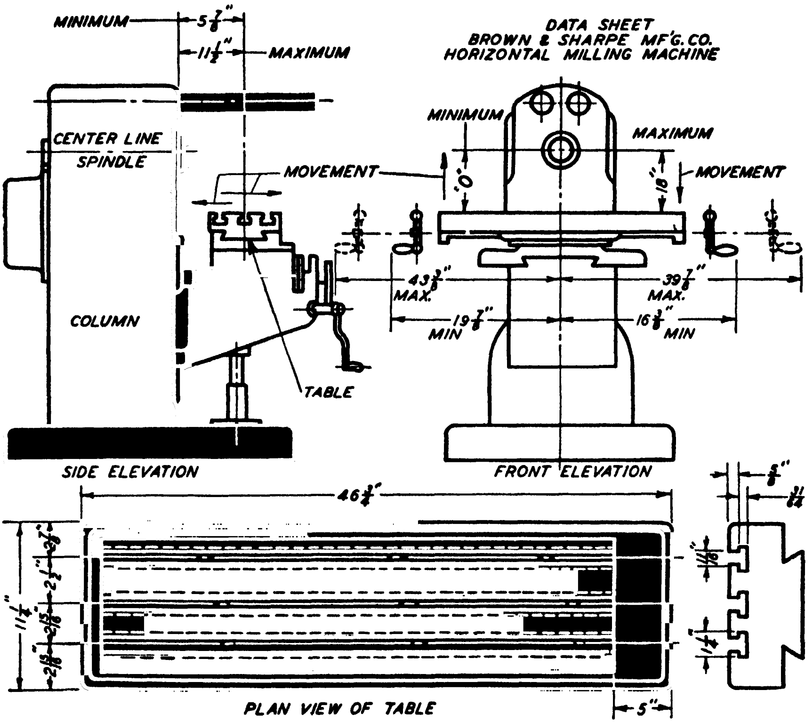


Fig 2 Milling Machine Data Sheet

vises are commercially available. By inserting jaws of various shapes a great many parts can be machined in a device of this kind

To design a milling fixture for milling a hub on a part that is made from a casting, a fixture similar to Fig. 4 is designed. This fixture consists of a cast-iron base that is machined on the bottom to obtain a true surface There is a U-lug on either end of this

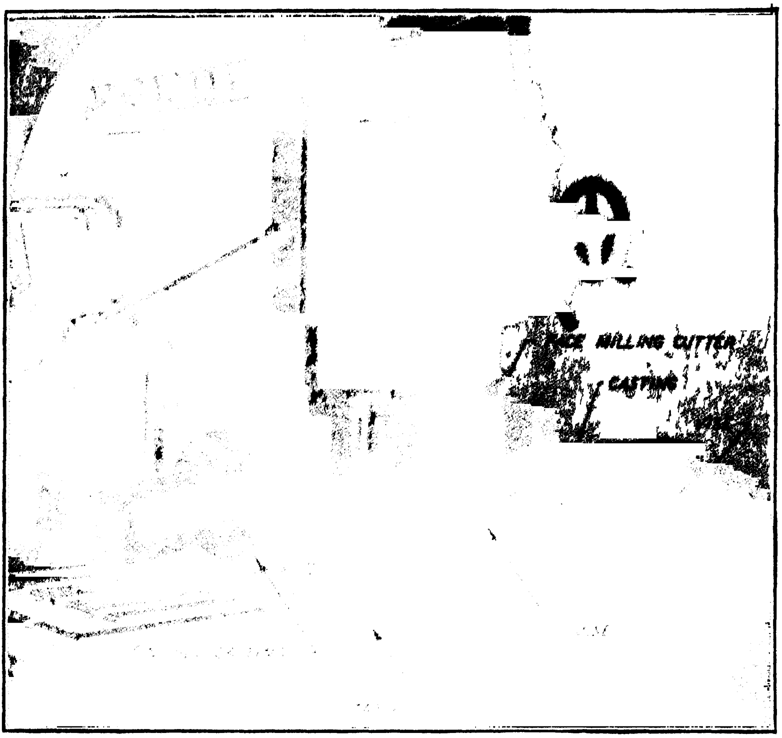


Fig 3 Adjustable Milling Machine Vise

milling fixture The bosses on the top of the base are spotfaced to provide for a combination locating pin and rest button An additional locating pin is designed to locate the casting in the proper position. A forged steel clamp with one end bent at a 90° angle is designed to hold the piece part rigidly for the milling operation This clamp has an elongated slot so that it is capable of being pulled out of the way to remove, or unload, the piece part. Note that the section that clamps the piece part has been milled out so that it will grip the work approximately on the center line of the hub.

This drawing is not dimensioned and is used for illustrating the fundamental principles of milling fixture design. It will be noted that there are two keys on the horizontal center line for locating this fixture on the milling machine table. The tail end of the clamp rests on the body of the fixture. This type of fixture is generally designed for low-quantity production. If a fixture of this type were to be designed for larger quantities, a hardened and ground tool-steel rest pad would be attached to the surface of the base. In addition. the clamp itself would be hardened on the resting points. This fixture is designed to be used in a vertical milling machine; however, this same fixture can be used in a horizontal milling machine by providing the proper width of milling cutter so that the entire boss would be milled at one pass.

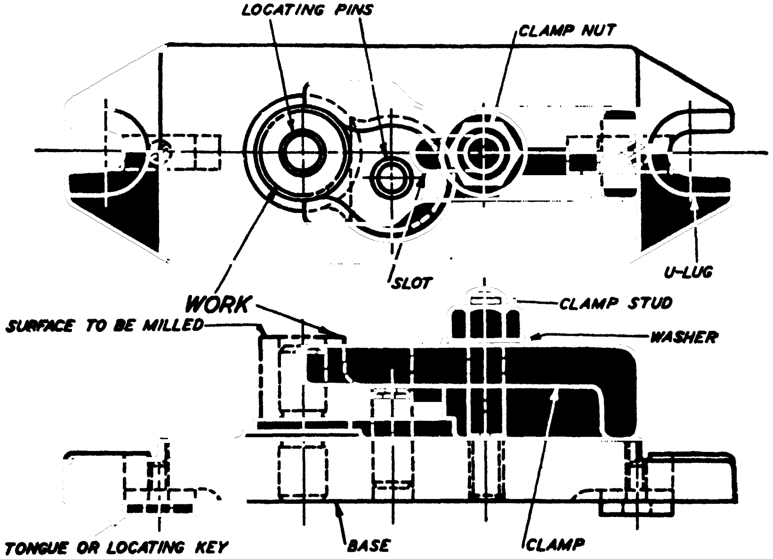


Fig. 4. Simple Milling Fixture for End Milling a Hub

To mill cylinder heads of internal combustion engines, a milling fixture illustrated by Fig. 5 is designed. It will be noted that this fixture is very rugged and is set low on the table. Two cylinder heads are milled simultaneously, and after the first setup a cylinder head is completely milled on each pass of the machine. You will note that the piece part at the right is upside down so that the under side of the cylinder-head casting can be machined. At the same time the top side of the left-hand piece part (with the bolt bosses) is machined. After this operation has been completed, the cylinder head on the right is turned over and moved to the left or front part of the fixture, where its top side with the cylinder-head bolt bosses is machined The clamping is controlled from the front side of the fixture by the screws and hand knobs shown on the front end. This is a very good example of rigid milling fixture design.

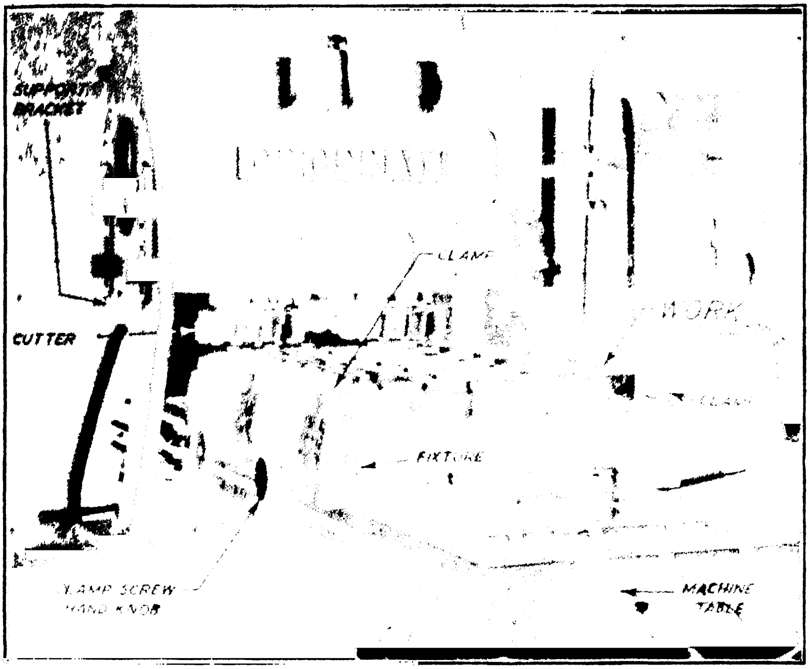


Fig. 5. Milling Fixture for Machining Tractor Engine Cylinder Heads, Shown on a Planer Type Milling Machine

Fixtures for Straddle Milling. To mill a piece part on both sides at one time, a straddle-milling fixture, Fig. 6, is designed. Two cutters are mounted on the milling machine arbor so that both surfaces or sides can be milled at one time, as well as a horizontal surface. Note that the cutter at the left mills both a horizontal and vertical surface as shown by the arrows.

This fixture has been designed with a cast-iron base in which

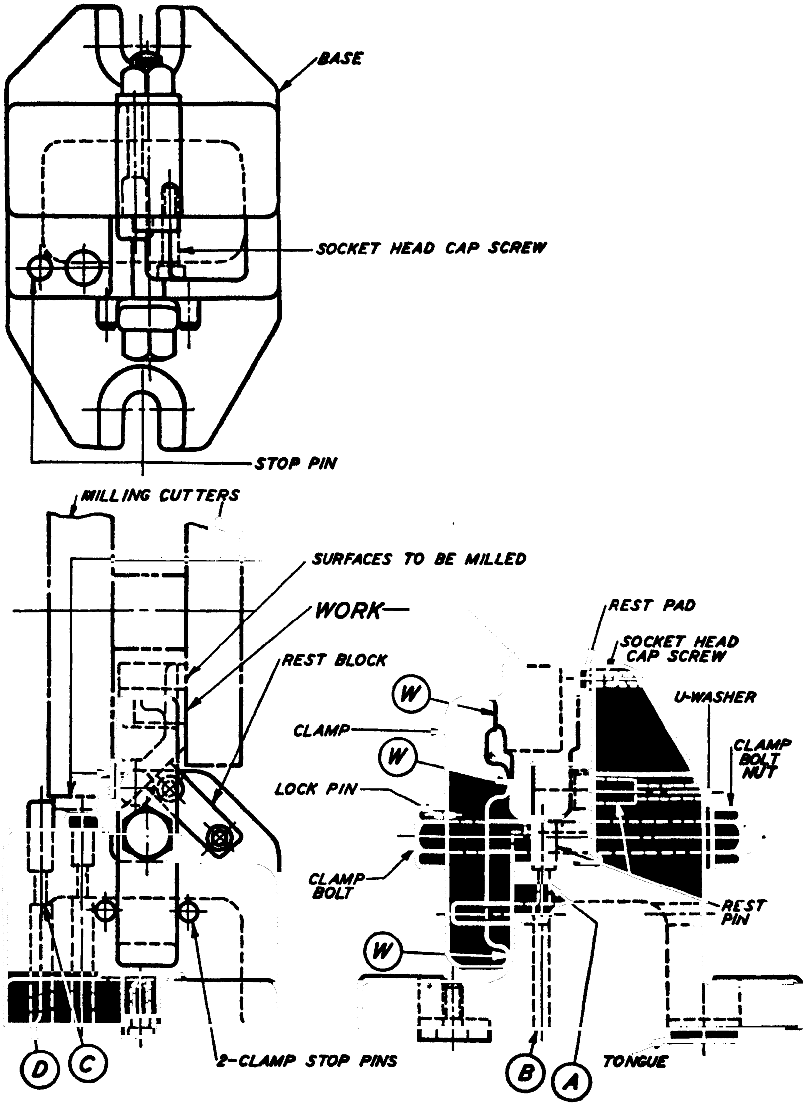


Fig. 6. Milling Fixture for Straddle-Milling Two Sides and Bottom Surface of a Casting

are inserted a hardened and ground stop pin, and rest pin, and on which are mounted a rest block and rest pad. These are provided for locating the work in the fixture. The clamp is designed to be made of cold-rolled steel, carburized, hardened and ground on the points where it comes in contact with the work and fixture. It is slotted to make it adjustable.

Two stop pins are located in the base of the fixture so that the clamp will be maintained in a vertical position at all times. On this piece part, which is a casting, the milling cutters are of different diameters so that they will not only straddle-mill this part, but the larger diameter cutter will mill the casting to the required depth on one side.

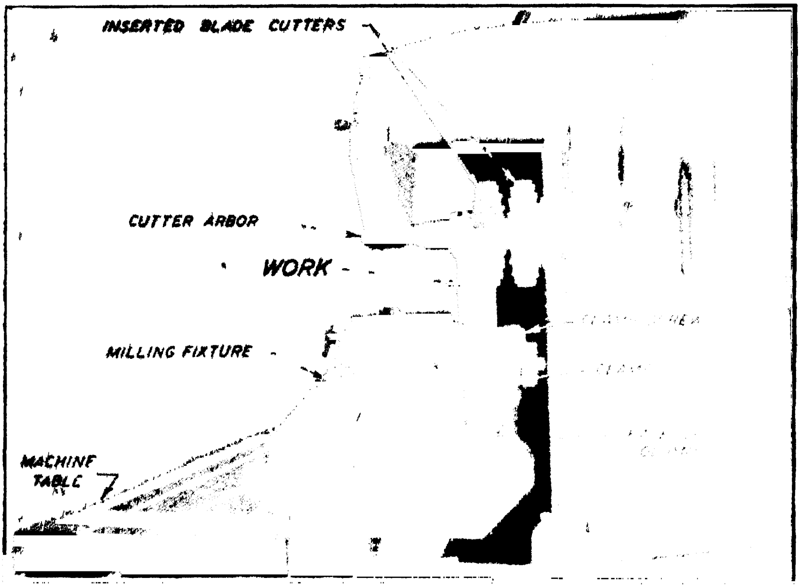
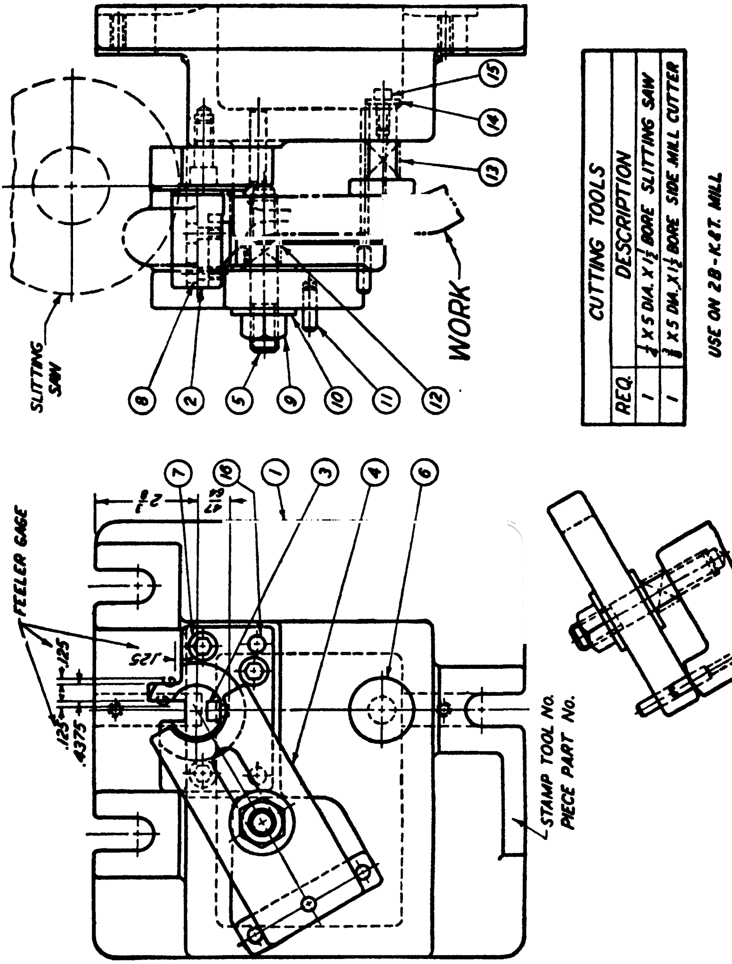


Fig. 7. Milling Fixture for Straddle-Milling a Bracket

In designing a straddle-milling fixture it is necessary to see that proper clearances are provided so that the cutters will not interfere with the fixture. These fixtures should be as low as possible and be consistent with good design.

Another example of straddle-milling fixture design is shown by Fig. 7. In this illustration the fixture, on account of the height of the work, has been allowed to overhang the milling machine table on the side nearest to the column face of the milling machine. On this particular job there is a special gang of cutters for milling the lower part of the piece part. This is accomplished by moving the table up to the proper position. When the table is lowered, the straddle-milling operation takes place by means of the two inserted-blade side milling cutters that are also mounted on the milling machine arbor. This is a low-production job, but it is a good example of what can be accomplished by the use of properly designed milling fixtures.



CUTTING TOOLS	
REQ.	DESCRIPTION
1	1/4 X 5 DIA. X 1½ BORE SLITTING SAW
1	3/8 X 5 DIA. X 1½ BORE SIDE MILL CUTTER

USE ON 2B-K.&T. MILL

Fig. 8. Assembly Drawing of a Milling Fixture to Split and Straddle-Mill an Engine Clutch Hand Lever

On some types of milling fixtures it is necessary to combine operations. Fig. 8 is an assembly drawing showing the layout of a milling fixture to split and straddle-mill an engine clutch hand lever. The base of this fixture, Fig. 9, is designed to be made of cast iron and note that there are three elongated slots cored in this casting so

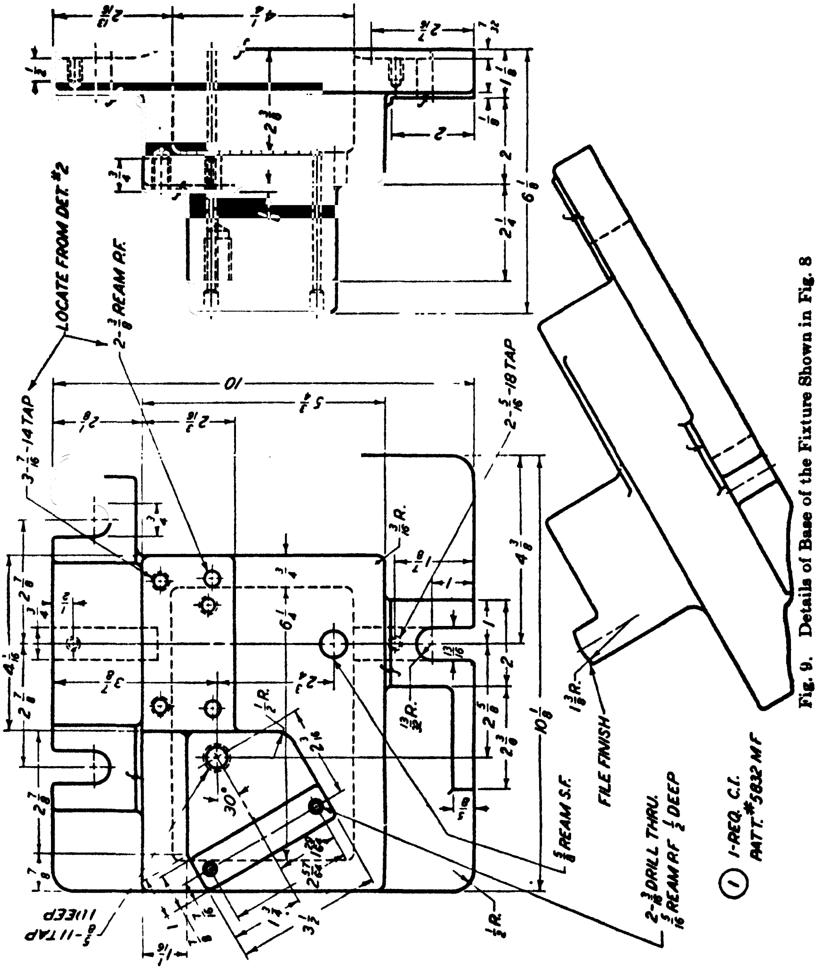
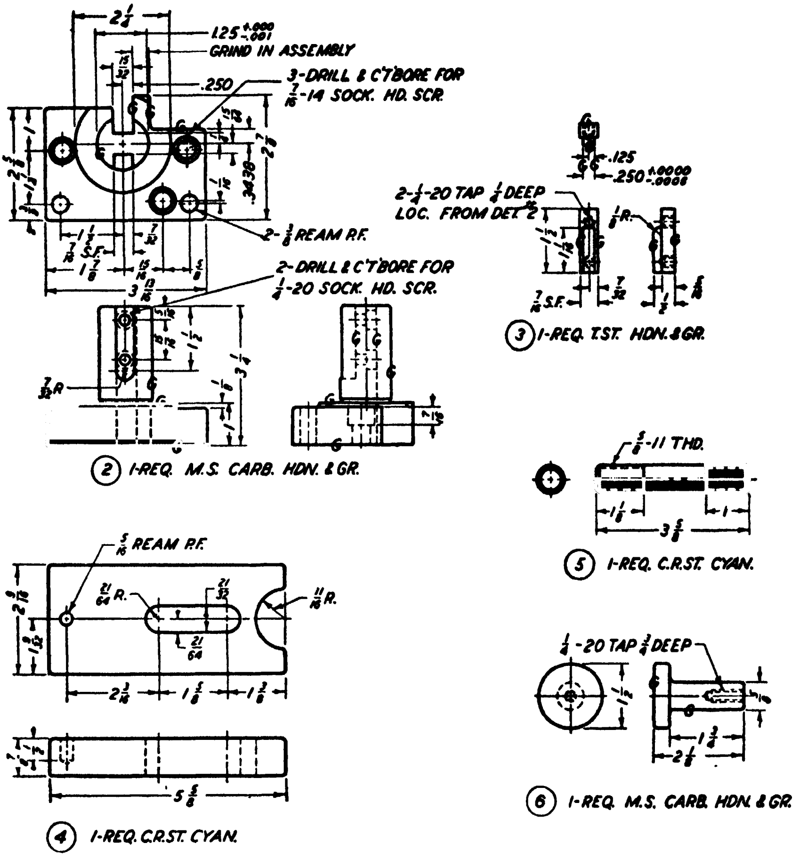


Fig. 9. Details of Base of the Fixture Shown in Fig. 8

that the base can be clamped securely to the milling machine table. In order to provide a heel for the clamp, a section of the base is finished by filing to a 1⅜″ radius. This is shown as a detail on Fig. 9. Fig. 10 is a drawing illustrating various details and the bill of material.



No.	NAME	REQ.	MATERIAL	STOCK SIZE
16	DOWELS	2	STANDARD	3/8 DIA. X 1 3/4
15	ALLEN SOCK. HEAD SCREW	1	STANDARD	1/4-20 X 3/4
14	WASHER	1	STANDARD	5/16 HOLE X 1/16 THICK
13	SPRING	1	SPRING WIRE	TO SUIT
12	SPRING	1	SPRING WIRE	TO SUIT
11	PINS	3	C.R.ST.	5/16 DIA. X 1
10	WASHERS	2	STANDARD	11/16 HOLE X 1/8 THICK
9	HEXAGON NUT	1	STANDARD	5/8-11
8	ALLEN SOCK. HEAD SCREW	2	STANDARD	1/4-20 X 1/2
7	ALLEN SOCK. HEAD SCREW	3	STANDARD	7/16-14 X 1 1/8
6	REST BUTTON	1	MACH. ST.	1 5/8 DIA. X 2 1/4
5	STUD	1	C.R.ST.	5/8 DIA. X 3 3/4
4	CLAMP	1	C.R.ST.	7/8 X 2 3/4 X 5 3/4
3	KEY	1	T.ST.	5/8 X 9/16 X 1 5/8
2	LOCATING PLUG	1	MACH. ST.	3 X 3 3/8 X 3 15/16
1	BASE	1	C.I.	

Fig. 10. Details and Bill of Materials for the Fixture Shown in Fig. 8

CUTTING TOOLS	
REQ	DESCRIPTION
2	$\frac{1}{2}$ X 5 DIA. X $1\frac{1}{4}$ BORE, SIDE MILLING CUTTERS

USE ON MILWAUKEE MILL

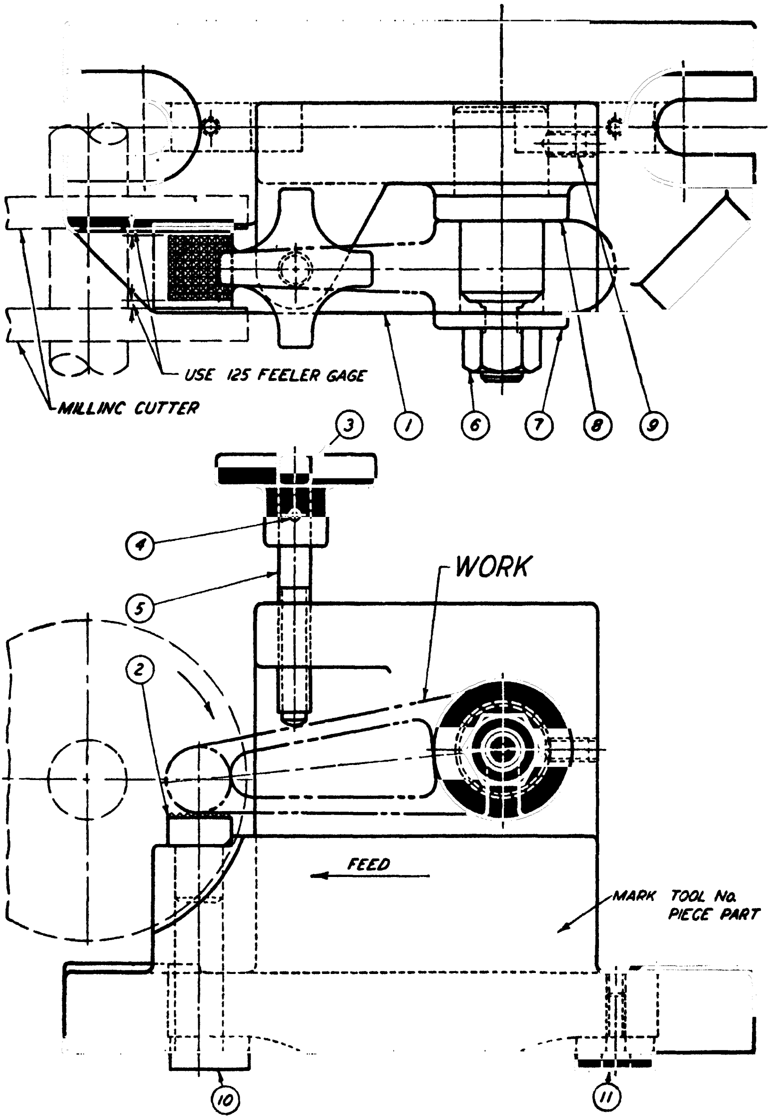


Fig. 11. Milling Fixture to Straddle-Mill the Small End of a Steering-Clutch Release Lever

Note that all locating parts are carburized, hardened, and ground. The clamp, detail *4*, is made of cold-rolled steel and is cyanide hardened. A 5/16″ reamed hole with a notation "press fit" on the tail end of this clamp is for the insertion of a pin (*11*) which will enable the operator to move the clamp in and out over the work piece. Detail *2*, Fig. 10, is a locating plug. This and the key (*3*) which is attached to it, properly locate the piece part in the fixture for the milling operations. The lever (work) has had a keyway broached in it prior to this milling operation, and it is necessary that this operation be located in definite relation to the keyway broached in the hub of the lever.

NO.	NAME	REQ.	MATERIAL	STOCK SIZE
11	SOCK HD CAP SCR	2	ST'D	5/16-18 X 7/8
10	KEY	2	ST'D	1/2 X 3/4 X 1 1/4
9	CONE POINT HDLESS SET SCR	1	ST'D	3/8-16 X 3/4
8	LOCATING PLUG	1	M.S	2 1/4 DIA X 4 3/8
7	WASHER	1	C R ST	2 1/4 DIA X 3/8
6	HEXAGON NUT	1	STD	5/8-11
5	SCREW	1	C R ST.	1/2 DIA X 3 7/8
4	PIN	1	C R ST	3/16 DIA X 1 1/4
3	HAND KNOB	1	ST'D	1/2-13
2	REST PAD	1	TS	1 1/8 X 1 1/8 X 1 5/8
1	BASE	1	C I	PATT #5856 MF

Fig. 12. Bill of Materials for the Fixture Shown in Fig 11

To straddle-mill the small end of a steering-clutch release lever, a milling fixture similar to Fig. 11 is designed. The bill of materials is shown on Fig. 12. It will be noted that the base (*1*) of this fixture is cast iron. Elongated slots are cast in the base. The pads around the slots are machined (see Fig. 13) to insure that the clamp bolts will seat properly. Two slots are milled in the bottom of the base to receive keys (*10*). The piece part is located in the fixture by means of a hardened and ground plug, detail *8*. A washer (*7*) and nut (*6*) are used to clamp the piece at this point. In addition a screw (*5*) is used to make sure that the piece part seats properly on the serrated rest pad, detail *2*. Fig. 13 shows the detail of the base (detail *1*) of this fixture with all necessary machining dimensions properly indicated.

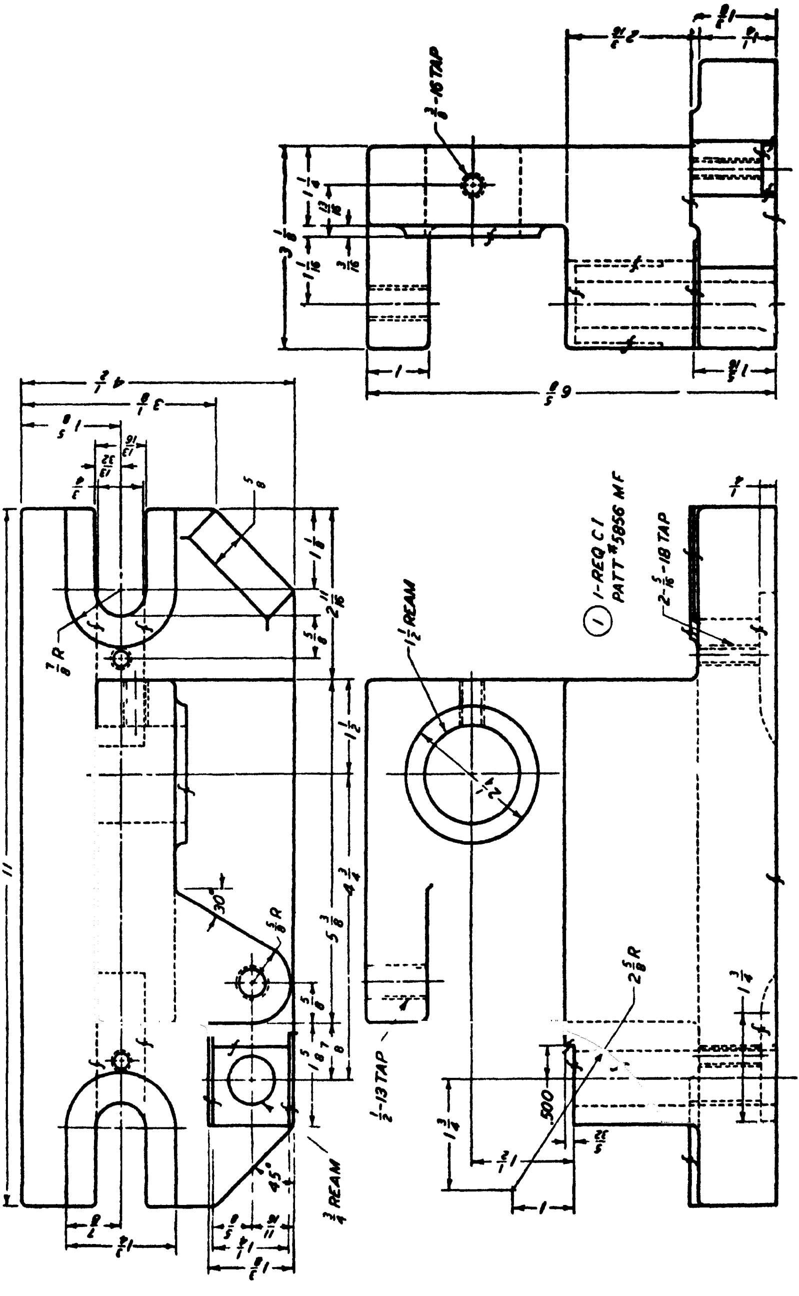


Fig. 13 Details of Base of Fixture Shown in Fig. 11

It will be noted that clearance has been provided for the diameter of the cutter. This is shown as a $2\frac{5}{8}''$ radius on the extreme left-hand side of this drawing. Fig. 14 is a drawing of the details. Detail *2* is the hardened and ground rest pad with serrated face. The serrations prevent the piece part from slipping when the bosses are being milled. This rest pad is made of tool steel and is hardened and ground to prevent wear.

The bore in the large end of the piece part slips over the locating plug, detail *8*. This locating plug has a thread to suit the clamping nut. A **U**-washer (detail *7*) is used, and attention should be given to the flats $\frac{3}{8}''$ wide that are milled on detail *8* in order to permit this **U**-washer to be placed over the locating plug. When the clamp nut is released, the **U**-washer can be slipped out and the piece part can be removed from the fixture without removing the nut from the locating plug.

In order to prevent this plug from turning in the fixture, a spot is drilled in the rear portion of the locating plug and a cone-point screw (*9*) is inserted in the base of the fixture to lock the locating plug in the proper position. In addition, a clamping screw (detail *5*) is used. This is to prevent the piece from moving upward when the bosses on the small end of the lever are being machined. This clamping screw (detail *5*) as will be noted from the assembly drawing, Fig. 11, has a cast-iron hand knob (*3*) attached to it by means of a pin (*4*). This hand knob permits the operator to exert the correct pressure, without much physical effort, to hold the piece part securely in the fixture. This design of milling fixture can readily be adapted to piece parts of a similar nature.

Keyway Fixtures. To mill keyways in shafts, a milling fixture similar to Fig. 15 may be designed. This is a comparatively simple type of fixture and, as will be noted, it involves some of the principles used in the design of jigs for drilling shafts, inasmuch as two hardened and ground **V**-blocks (detail *3*) are mounted on the base (*1*) of this fixture to locate the shaft and clamp it securely. By carefully studying Fig. 15 it will be noted that this fixture consists of a cold-rolled steel base with slots milled on either end for the two locating keys, detail *7*. A Woodruff keyway cutter is held in a chuck that is mounted in the milling machine for cutting the keyway. A feeler gage (Section *A-A*) is used to determine the depth of cut.

A spring (*15*) is mounted on the clamp stud (*11*) so as to move the clamp up when the nut (*12*) is released. This allows the work to be removed readily.

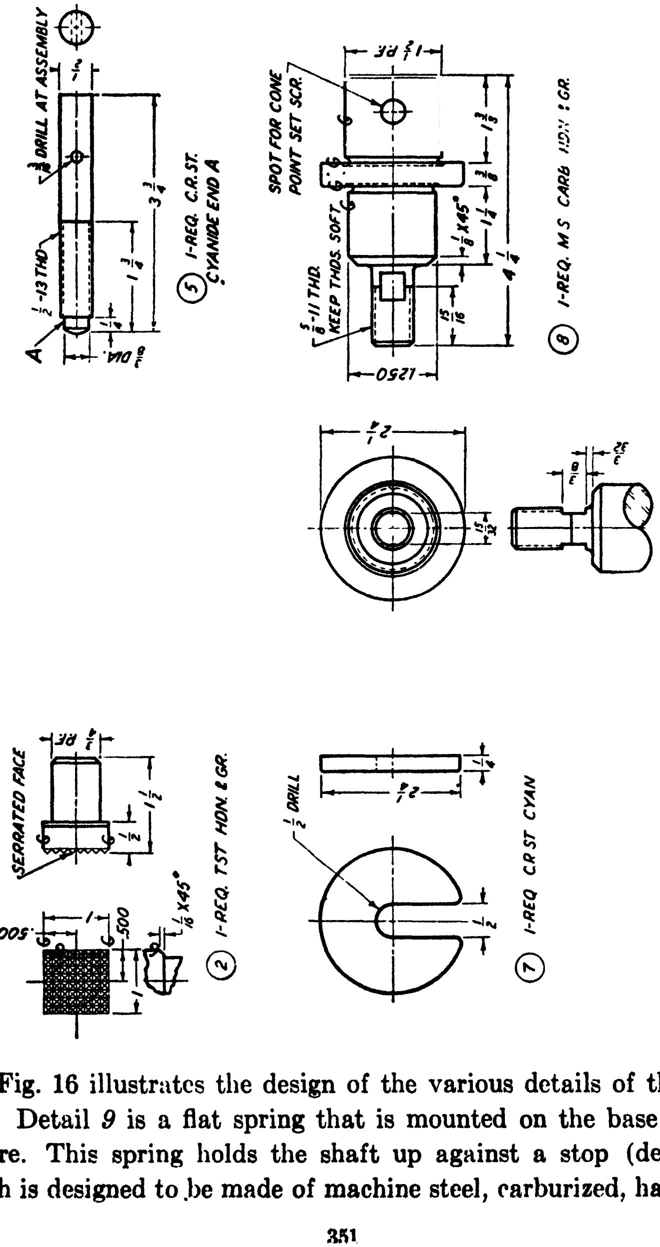


Fig. 14. Details of Fixture Shown in Fig. 11

Fig. 16 illustrates the design of the various details of this fixture. Detail *9* is a flat spring that is mounted on the base of the fixture. This spring holds the shaft up against a stop (detail *2*) which is designed to be made of machine steel, carburized, hardened

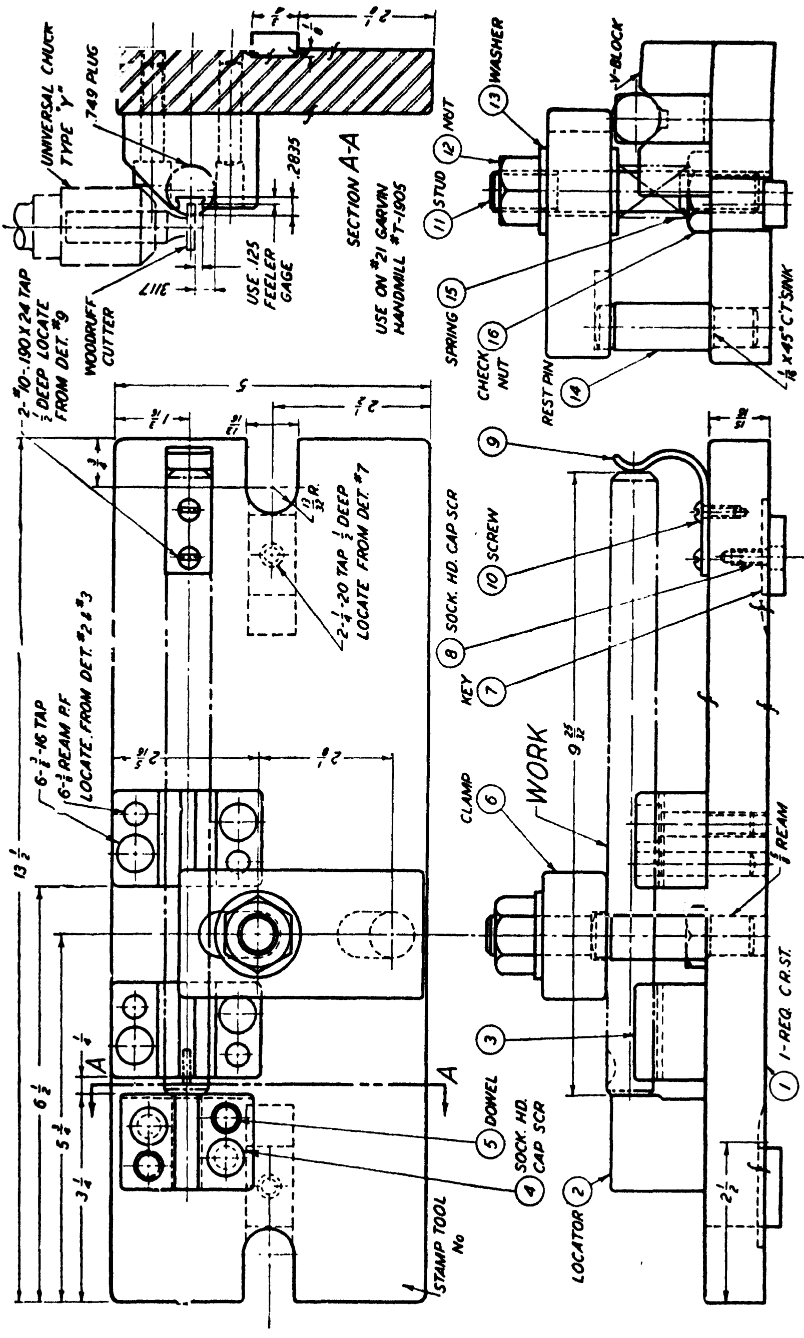


Fig. 15. Fixture to Mill Keyways in Shafts

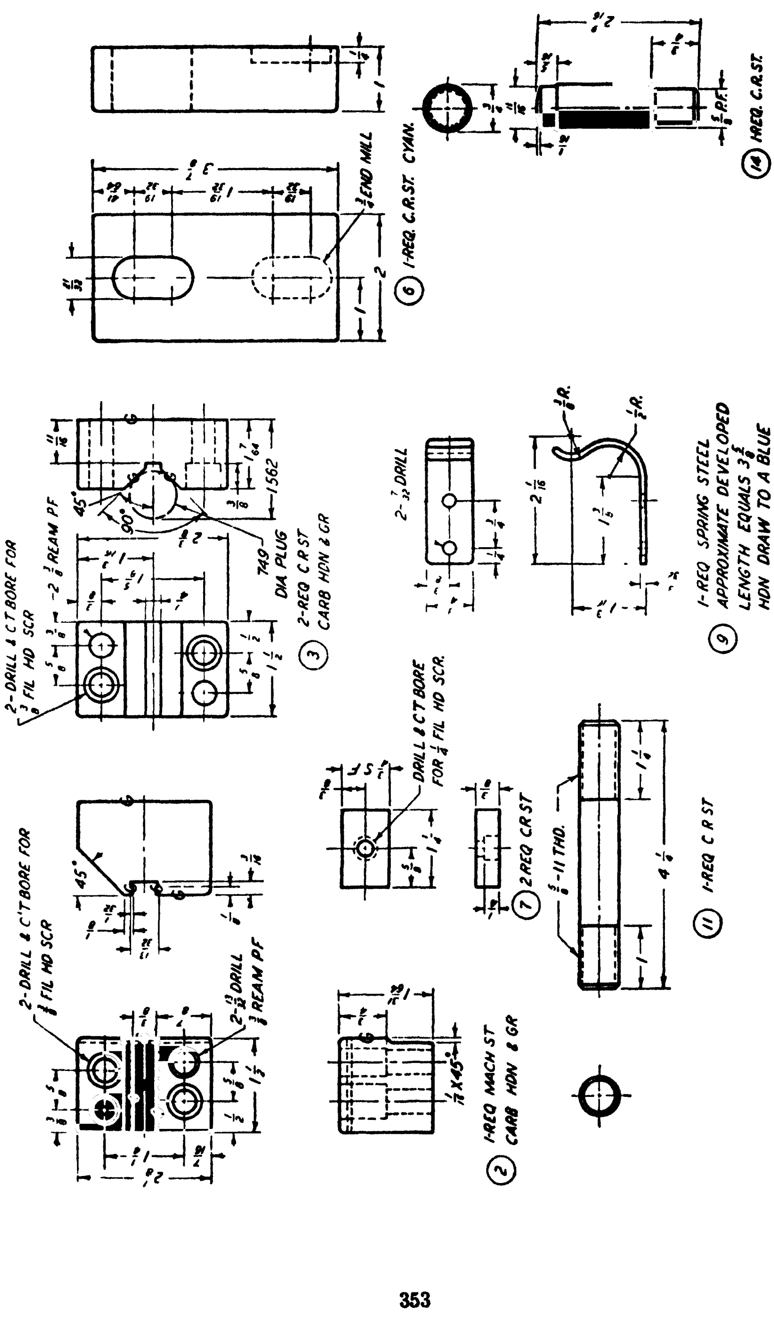

2-DRILL & C'T BORE FOR 3/8 FIL HD SCR
2-3/8 REAM PF
45°
90°
749 DIA PLUG
1562
③ 2-REQ C R ST CARB HDN & GR
3/4 END MILL
⑥ 1-REQ. C.R.ST. CYAN.
5/8 P.F.
⑭ 1-REQ. C.R.ST.
2-7/32 DRILL
⑨ 1-REQ SPRING STEEL APPROXIMATE DEVELOPED LENGTH EQUALS 3 5/8 HDN DRAW TO A BLUE
DRILL & C T BORE FOR 1/4 FIL HD SCR.
⑦ 2 REQ C R ST
5/8-11 THD.
⑪ 1-REQ C R ST
2-DRILL & C'T BORE FOR 1/4 FIL HD SCR
2-13/32 DRILL 3/8 REAM PF
1/16 X 45°
② 1-REQ MACH ST CARB HDN & GR

Fig 16. Details of Fixture Shown in Fig. 15

and ground to resist wear. The clamp (*detail 6*) *has an elongated* slot to fit the clamp stud. On the tail end of the clamp, a slot ¾″ wide is milled to ¼″ deep. This is on the bottom side of the clamp and holds it in place by means of a rest pin (detail *14*) that is pressed into the milling fixture base. This pin prevents the clamp from twisting around on the work and from sliding too far.

Fixtures for Milling Slots in Levers. On automobile and tractor production as well as other types of machine work a great many levers are used. These levers are sometimes fastened to a shaft by a binder bolt. This binding action takes place by means of a slot that is milled in one end of the lever so that a binder bolt can be inserted at right angles to the slot in order to bind the two sections of the lever together. To mill these slots in levers, a fixture similar to the one illustrated by Figs. 17A and 17B is designed. The base (detail *1*) of this fixture is designed to be made of cast iron and is of the angle plate type. The bottom and inside face (this inside face contacts details *3* and *6*) of this casting are machined to obtain true surfaces. A keyway is machined in the bottom for keys (*12*) which locate the fixture on the milling machine table. A locating pin (*3*) for the small bore of this lever is mounted in the face of the angle plate, and a locating plug (*6*) is mounted in the upper portion. Details of this locating plug are shown by Fig. 18. This plug is designed to be made out of machine steel and is carburized, hardened and ground. A ½″ slot has been milled clear through this locating plug so that the milling cutter will have clearance in milling the slot in the lever. The clamp, detail *4* Fig. 18, has the usual standard elongated slot; in addition, a ⅝″ slot is milled to ⅜″ depth from the rear portion of this clamp to the elongated slot. This slot is designed so that when the clamp rest (detail *2*) is mounted in the fixture, the clamp will slide forward and back, and the slot will prevent it from twisting or turning when the clamp nut is tightened to hold the work securely in the fixture.

The clamps shown in Figs. 8, 15, and 17A are presented to acquaint the tool designer with different means of clamping, and to show the different methods that can be used to prevent clamps from turning or getting out of position in the fixture.

Fixtures for Milling Flanges. To mill flanges on air-cleaner pipes, inlets and exhaust manifolds, milling fixtures similar to Fig. 19

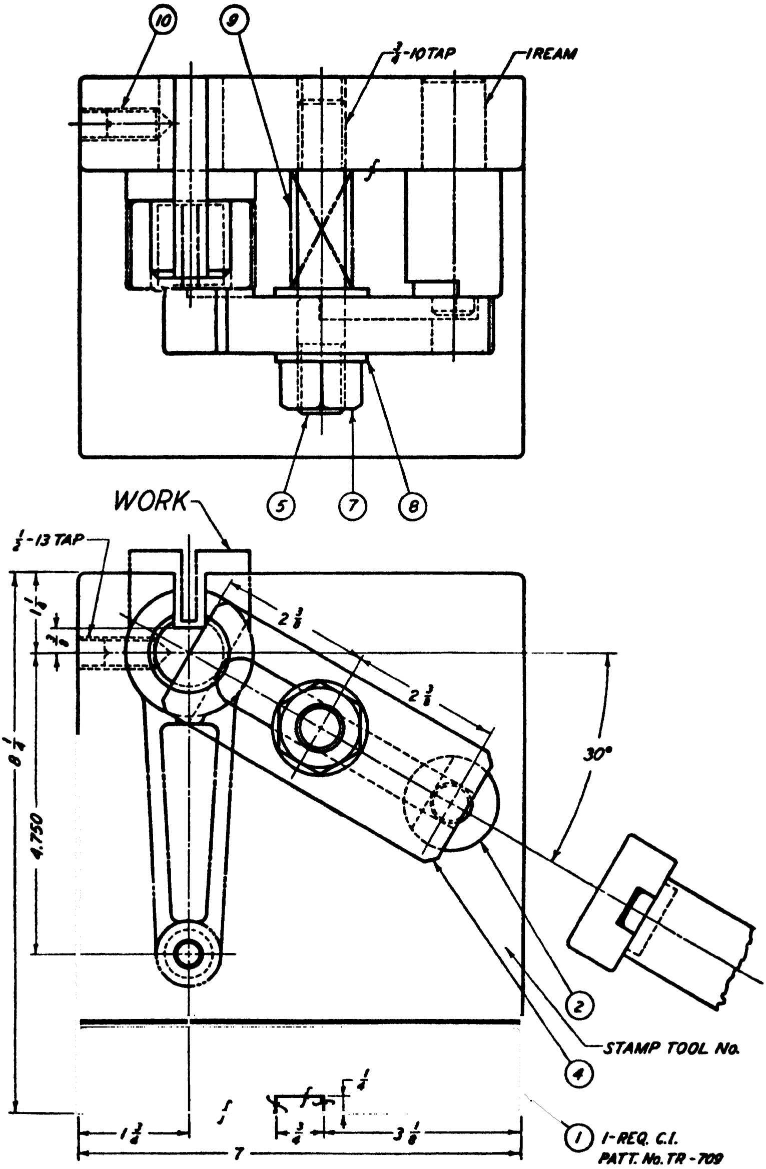


Fig. 17A. Fixture for Milling Slot in Steering-Clutch Release Lever

CUTTING TOOLS	
REQ.	DESCRIPTION
1	½ X 5 DIA. X 1½ BORE PLAIN MILL CUTTER

12	KEY	2	ST'D	TO SUIT
11	FIL. HD. SCR.	2	ST'D.	5/16-18 X ¾
10	CONE POINT SET SCR.	1	ST'D.	½-13 X 1
9	SPRING	1	ST'D	TO SUIT
8	WASHER	2	ST'D.	¾ ST'D.
7	HEX. NUT	1	ST D.	¾-10
No.	NAME	REQ	MAT'L.	SIZE

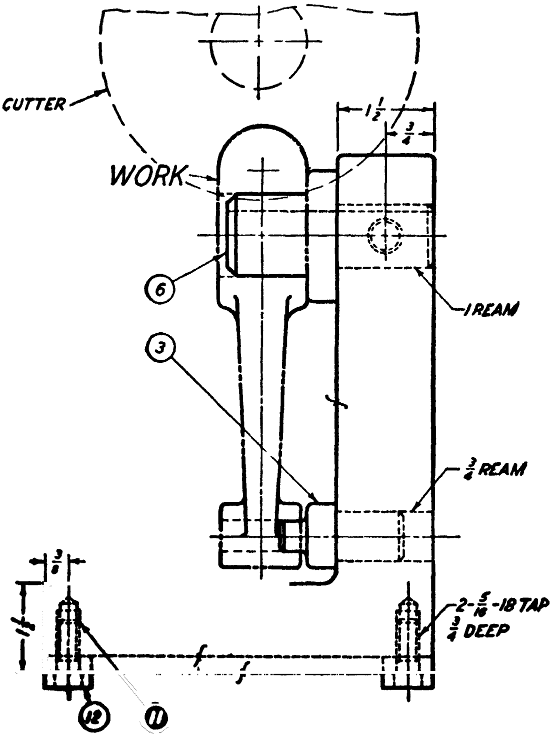


Fig. 17B. Part of Assembly Drawing and Bill of Materials for the Fixture Shown in Fig. 17A

are designed. This drawing shows the location of various details that are designed for a fixture of this type. The clamping means employed here is a combination of a hinged and swinging clamp to permit the rapid loading and unloading of the piece parts. Fig. 20

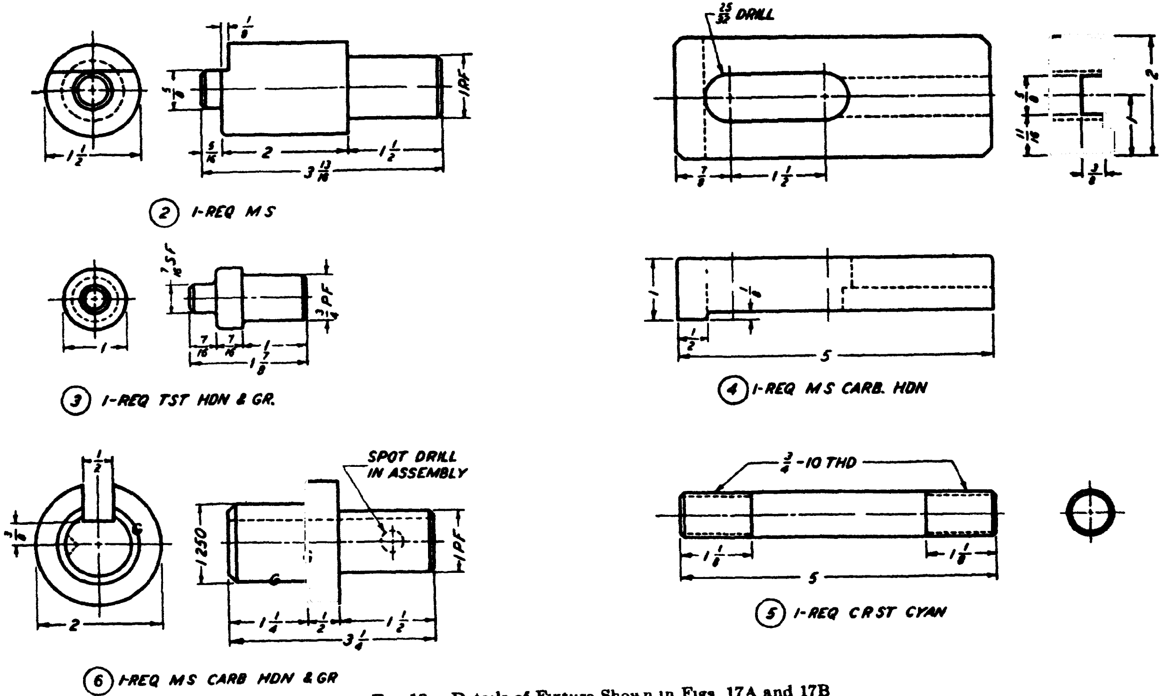


Fig 18 Details of Fixture Shown in Figs 17A and 17B

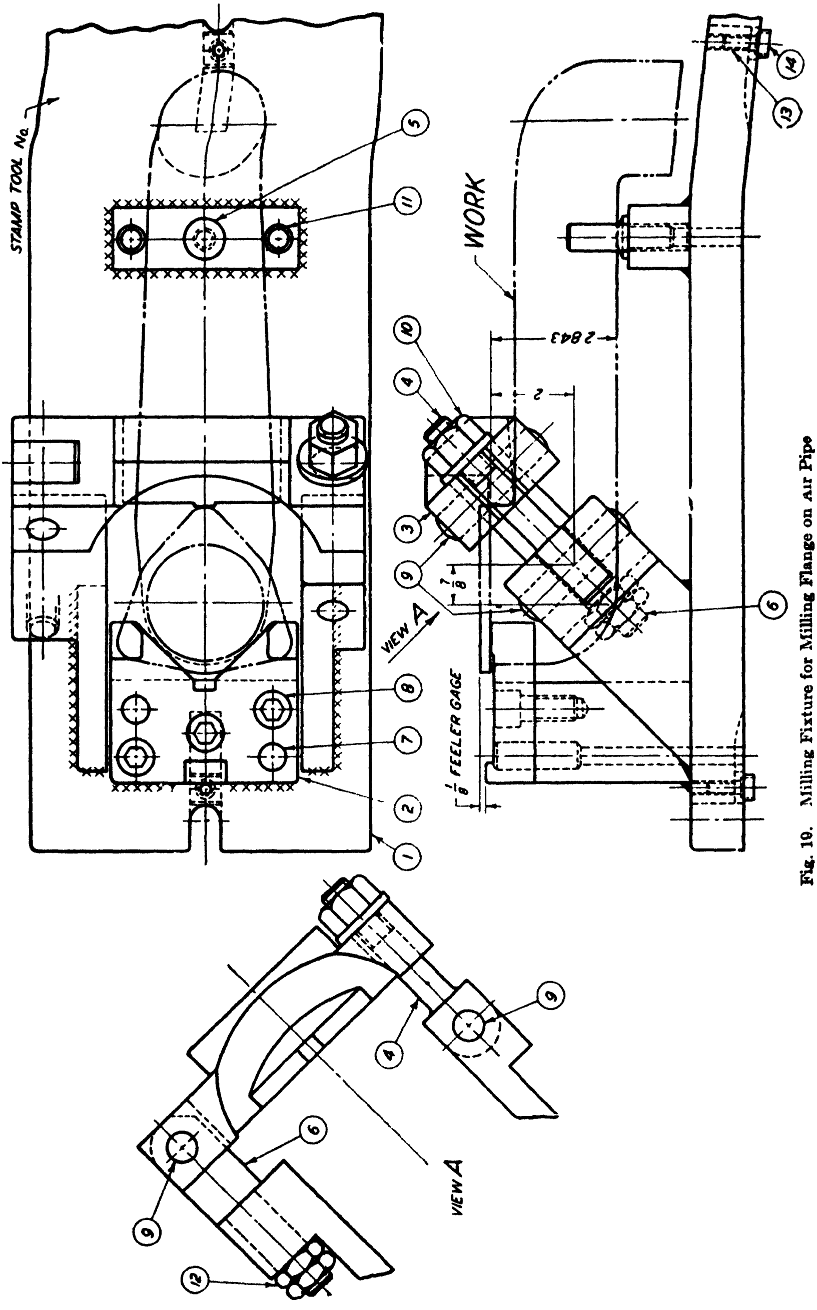
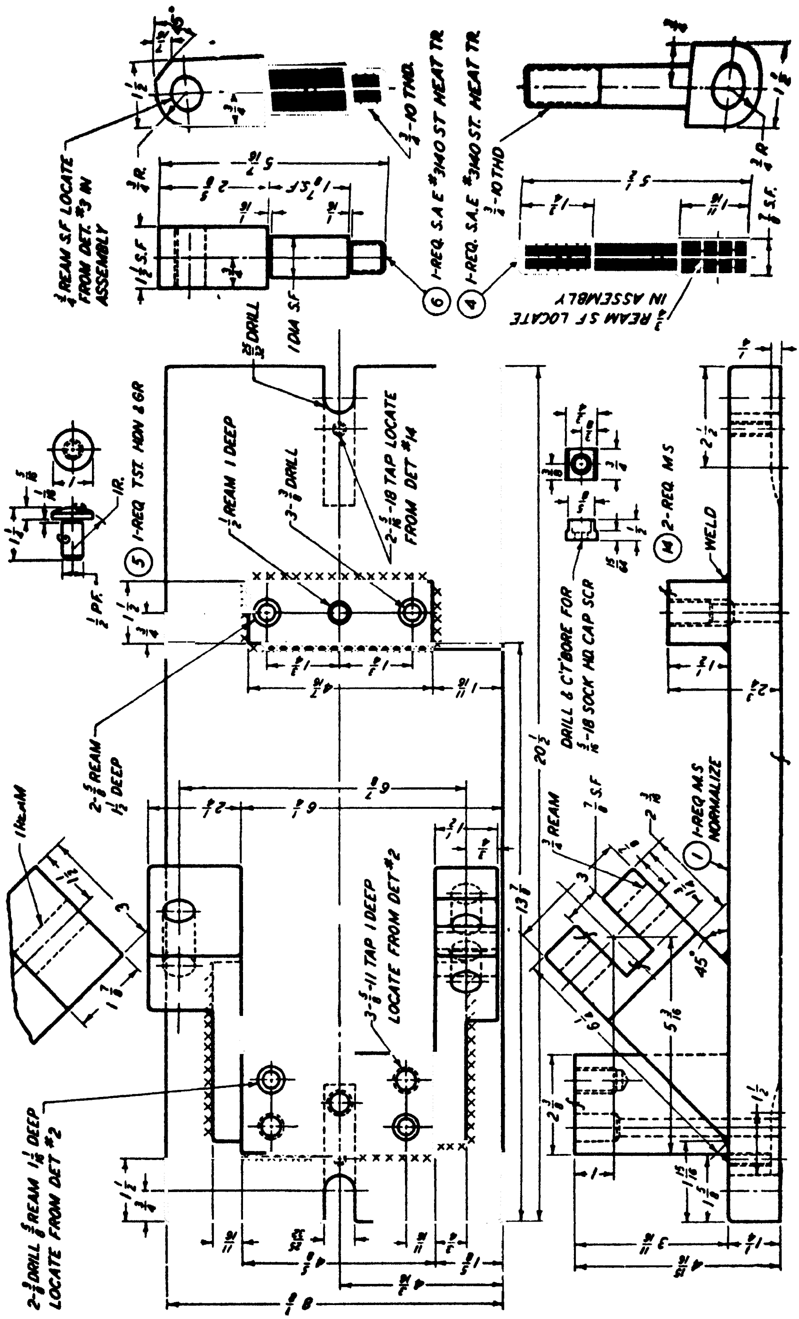
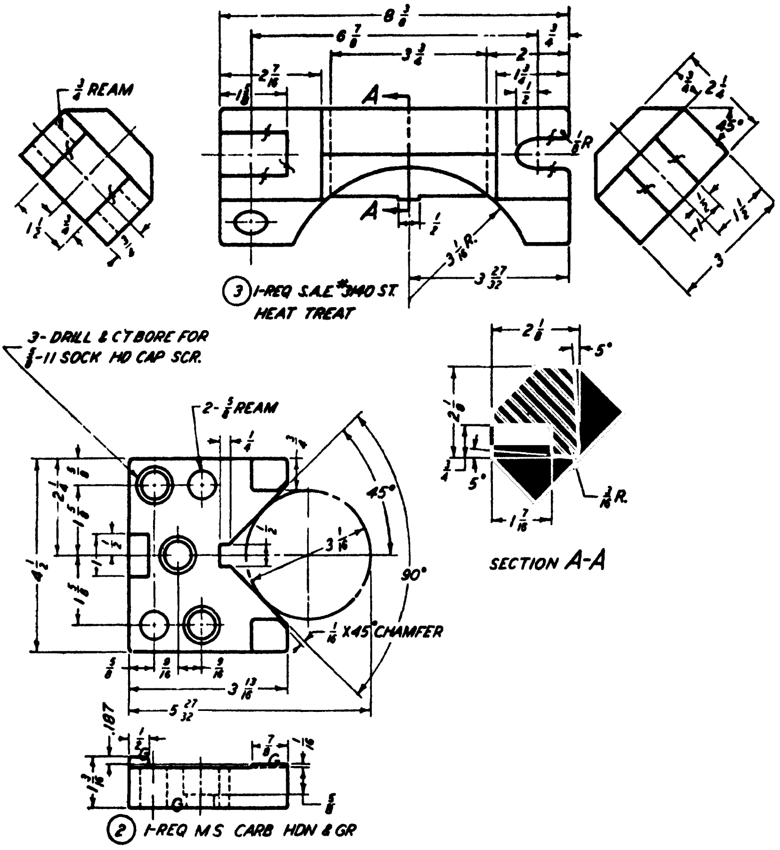


Fig. 19. Milling Fixture for Milling Flange on Air Pipe



2-3/8 DRILL 5/8 REAM 1 1/16 DEEP LOCATE FROM DET #2
1 REAM
2-5/8 REAM 1 1/2 DEEP
1/2 P.F.
1 R.
5 1-REQ. T.S.T. HDN & GR
1/4 REAM S.F. LOCATE FROM DET. #3 IN ASSEMBLY
1/2 REAM 1 DEEP
3-3/8 DRILL
2-5/16-18 TAP LOCATE FROM DET #14
23/32 DRILL
1 DIA S.F.
3-5/8-11 TAP 1 DEEP LOCATE FROM DET #2
6 1-REQ. S.A.E. #3140 ST. HEAT TR.
4 1-REQ. S.A.E. #3140 ST. HEAT TR.
3/4-10 THD.
3/4-10 THD
3/4 REAM S.F. LOCATE IN ASSEMBLY
DRILL & C'BORE FOR 5/16-18 SOCK HD. CAP SCR
M 2-REQ. M.S.
WELD
3/4 REAM
7/8 S.F.
1 1-REQ. M.S. NORMALIZE
45°
20 1/2
13 7/8
8 7/8
3/4 R.
7/8 S.F.

Fig 20. Details of the Fixture Shown in Fig. 19



13	SOCK. HD CAP SCR	STD	2	5/16-18 X 3/4
12	LOCK NUT	STD	2	3/4-10
11	PIN	C R ST	2	5/8 DIA X 3
10	NUT WELDED TO WASHER	STD	1	3/4-10
9	PIN	C R ST	2	3/4 DIA. X 3
8	SOCK HD. CAP SCR	STD	3	5/8-11 X 1 1/4
7	DOWEL	STD.	2	5/8 DIA X 2
NO.	NAME	MAT'L	REQ	SIZE

Fig. 21. Additional Details and Bill of Materials for the Fixture Shown in Fig. 19

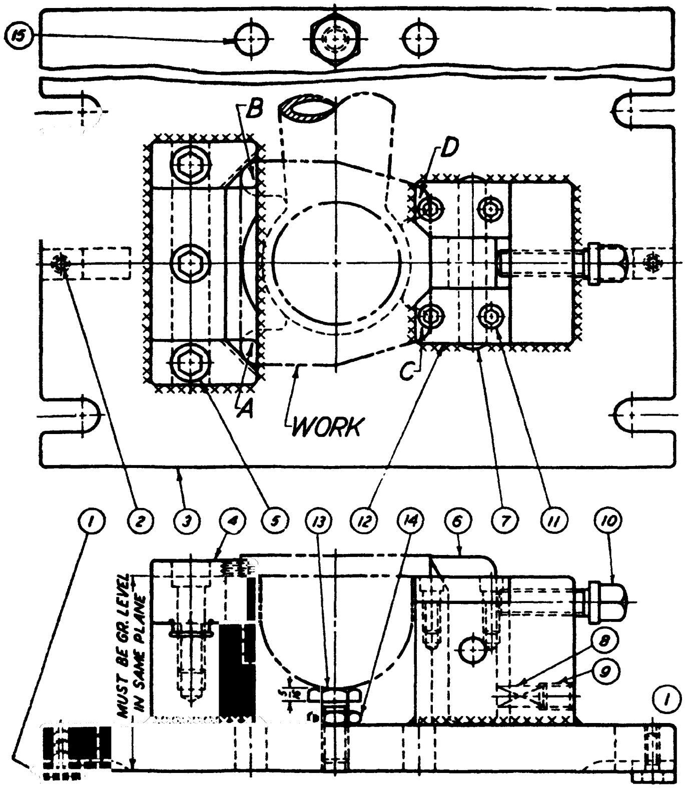
illustrates detail *1*, the design of the base of this milling fixture. The various sections are welded in place, after which the base is normalized to relieve stresses. Designs of details *4*, *5*, *6*, and *14* are also shown in this illustration.

Fig. 21 shows additional details. The **V**-block (detail *2*) is shown mounted on the extreme left-hand end of the assembly drawing, Fig. 19. Detail *3*, Fig. 21, is a difficult piece to show and it will be noted that three views have been drawn, in addition to the top view, in order to illustrate the design. The yoke (detail *3*) is mounted to the fixture by means of a pin (*9*) and detail *6*. To provide adjustment, two nuts (*12*) are used, one nut acting as a lock nut. Referring again to detail *3*, Fig. 21, this clamping yoke is slotted on the right-hand end for a latch screw (detail *4*). The latch screw (*4*) pivots on a pin (*9*) after nut *10* is loosened, allowing the yoke to swing to the left on another pin (*9*). This facilitates removal of the piece part. This design is frequently employed for work of this type and on jobs where it would be hard to clamp by any other means.

A fixture similar to Fig. 22 is frequently designed for use in milling flanges, pipes, and manifolds because of their peculiar contours and the difficulty experienced in holding such work in the proper position. This fixture, as will be noted, has a positive stop (*4*) in the form of a **V**-block. This is serrated in order to grip the piece properly. The clamp (*6*) has a fulcrum point which is below the center line so that when the clamp screw, (*10*) is applied against the clamp, the work piece is held down against the triangular surfaces *A*, *B*, *C*, and *D*, and against detail *13*.

The base of this milling fixture, detail *3* Fig. 23, is designed to be made of welded steel construction. All necessary machining dimensions are put on the drawings to aid the tool room. Detail *4* shows the design of the positive locating means. It will be noted that this detail is made of machine steel and is carburized, hardened and ground. The serrations, that are at an angle of 45° from the center line, are to prevent the piece part from slipping upwards when the part is clamped in the fixture. Detail *6* shows the design of the clamp. This is made of machine steel and is carburized, hardened and ground to prevent wear.

By referring again to Fig. 22 it will be noted that a spring,



CUTTING TOOLS	
REQ.	DESCRIPTION
1	6 DIA. CUTTER

No.	NAME	REQ.	MAT'L.	SIZE
15	PIN	2	DR. ROD	$\frac{3}{4}$ DIA. X $4\frac{1}{4}$
14	LOCK NUT	1	ST'D.	$\frac{5}{8}$-11
13	HEX. HD. CAP SCR.	1	ST'D.	$\frac{5}{8}$-11 X $1\frac{1}{2}$
11	SOCK. HD. CAP SCR.	4	ST'D.	$\frac{3}{8}$-16 X 1
10	COLLAR SCR.	1	ST'D.	$\frac{5}{8}$-11 X $2\frac{1}{4}$
9	SOCK. SET SCR.	1	ST'D.	$\frac{5}{8}$-11 X $\frac{3}{4}$
8	SPRING	1	SP. ST.	TO SUIT
7	PIN	1	DR. ROD	$\frac{5}{8}$ DIA. X 4
5	SOCK. HD. SCR.	3	ST'D.	$\frac{5}{8}$-11 X 2
2	SOCK. HD. SCR.	3	ST'D.	$\frac{5}{16}$-18 X $\frac{3}{4}$

USE ON CINN. VERTICAL MILL

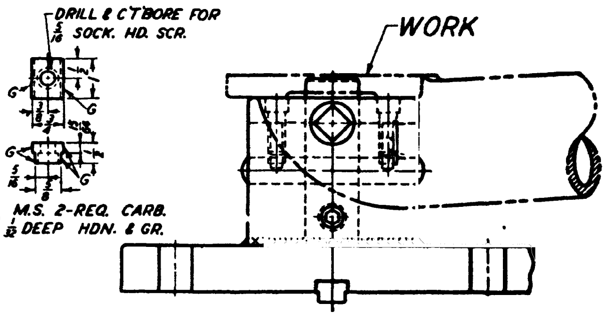

DRILL & C'TBORE FOR $\frac{5}{16}$ SOCK. HD. SCR.
G
G
G
G
1
M.S. 2-REQ. CARB. $\frac{1}{32}$ DEEP HDN. & GR.
WORK

Fig. 22. Fixture to Mill Flange on Air Cleaner Pice

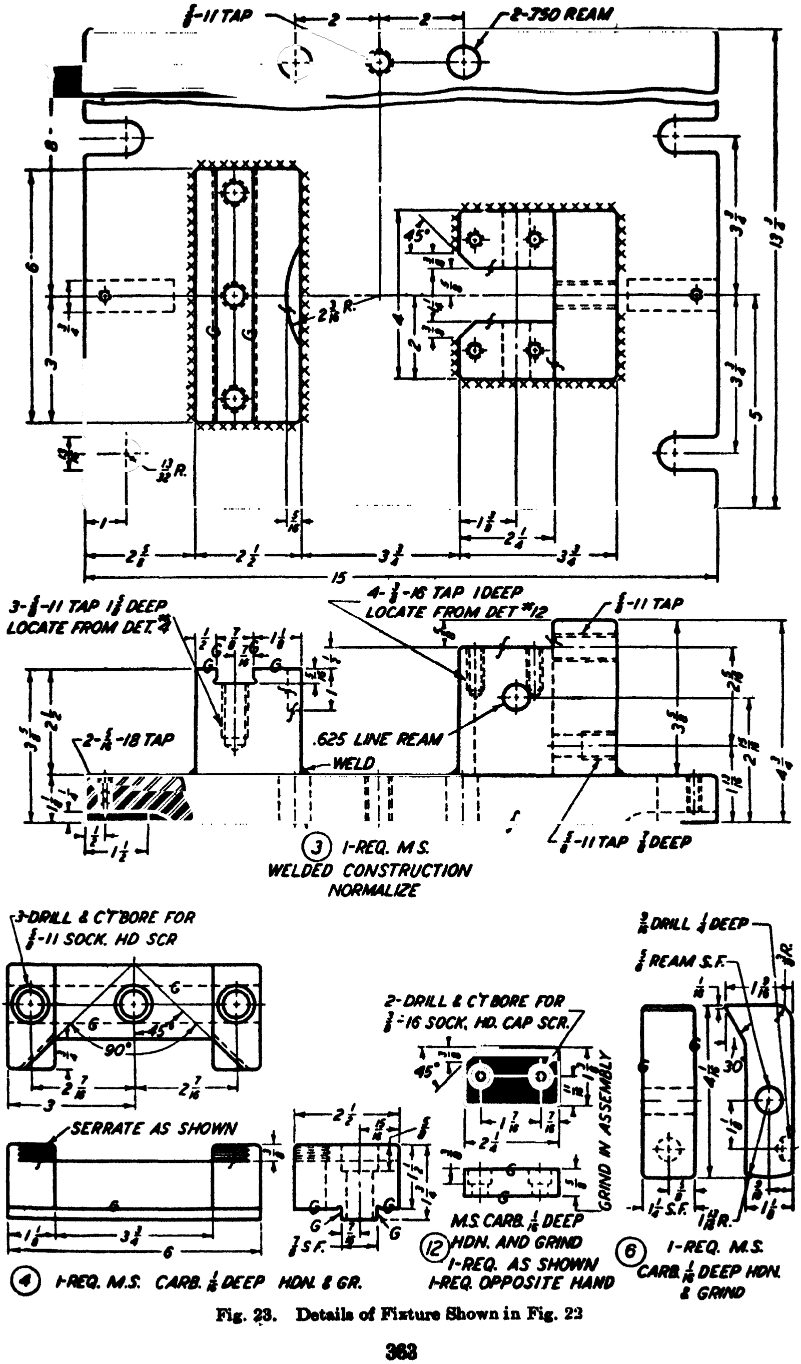


Fig. 23. Details of Fixture Shown in Fig. 22

detail *8*, is mounted in the fixture to engage the lower part of the clamp so that when the clamping screw (detail *10*) is released, the clamp (detail *6*) will spring back from the work, permitting ready removal of the piece part. The design of this fixture should be carefully studied by the tool designer, as ideas embodied in it can frequently be used on milling fixtures.

In designing milling fixtures the tool designer should keep in mind that where production warrants it, fixtures should be designed to hold as many piece parts as possible, and still be consistent with ease of handling, loading, and unloading the piece parts. Fig. 24 is a photograph of a double milling fixture to machine the top and bottom of a refrigerator compressor cylinder. The design of this fixture is very rugged, as can be seen from this illustration. The clamps are extremely heavy so as to clamp this piece part securely in the fixture. It will be noted that these compressor cylinders are put in the fixture in opposite directions and the milling machine is of a production type with two inserted-blade milling cutters. This is a good illustration of a rigid type of milling fixture.

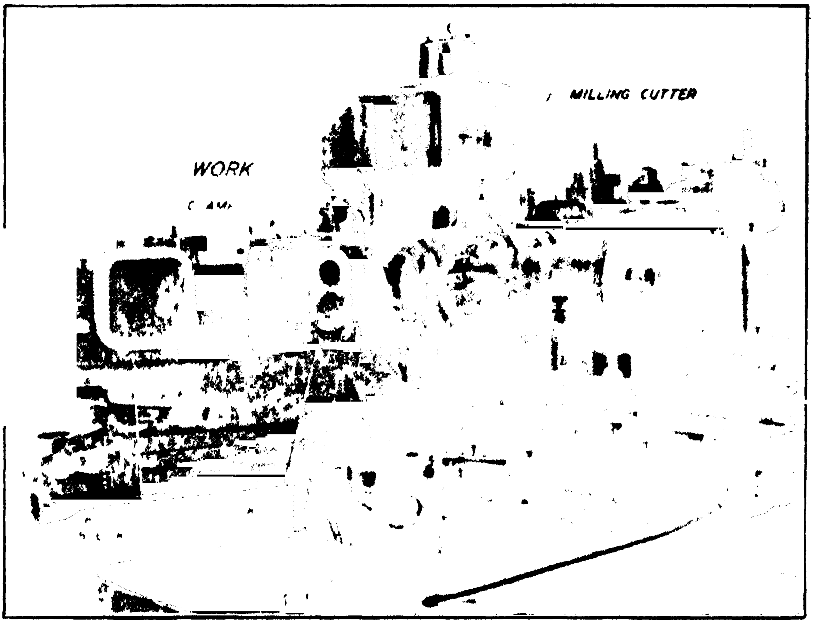


Fig. 24. Double Milling Fixture for Machining Top and Bottom of a Refrigerator Compressor Cylinder

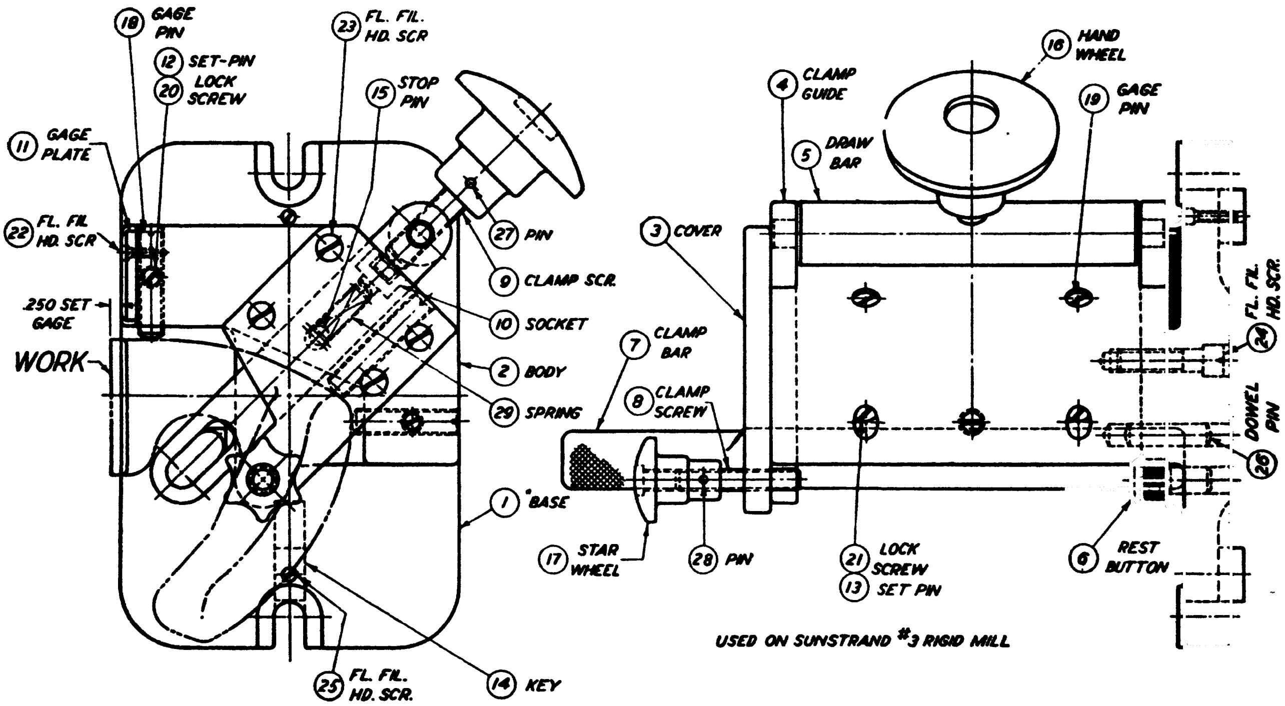


Fig. 25. Assembly Drawing of Milling Fixture for Milling a Surface on a Gear Shift Lever Quadrant

On some types of milling operation, due to the irregularity of design of the part to be machined, it is sometimes difficult to design a fixture that will hold this piece in the correct position for milling.

Fig. 25 is an assembly drawing of a milling fixture for milling a surface on a gear shift lever quadrant. The piece part and the surface to be machined are shown in this drawing. The details of the design are shown by Figs. 26A, 26B, and 26C. The base, detail *1*, is made from a gray iron casting.

The body of the fixture (detail *2*) is designed to be made of a gray iron casting to prevent excess machining that would ordinarily be done if it were made from steel. This body has an elongated slot machined in it to accommodate a clamping bar, detail *7*. This clamping bar is made of SAE 1020 steel, is hardened and ground, and has a 90° angular surface ground on it to locate it on the radius of the piece part. By carefully studying the details of this milling fixture and comparing them with the assembly drawing, Fig. 25, the location of these details can be determined. As stated before, the irregular shape of this casting makes it somewhat difficult to hold properly. All points in the fixture against which the piece part is located are hardened and ground, and clamping screws are provided where necessary to hold the work securely for the milling operation. This is a good example of difficult milling fixture design, and the drawing clearly illustrates the various details. It is also a good example of drawing, as all parts of the milling fixture have been given titles so that the toolmaker can readily identify them.

In the manufacture of washing machines there are a number of parts that are milled; among them are gear housings. Fig. 27 illustrates a fixture for face milling four of these housings at one time. This is an example of good milling fixture design. The piece part has been bored in the lower section prior to the milling operation. These gear housings are then located in the milling fixture by means of fixed and movable locating plugs that are actuated by levers which can be seen in the extreme left-hand side of this photograph. The housing rests against hardened and ground pins inserted in the fixture, and two clamps are provided, each clamps two piece parts, one piece part on either side of the fixture. Additional screws are also provided to prevent movement of this part, and two inserted-blade face-milling cutters are located in this pro-

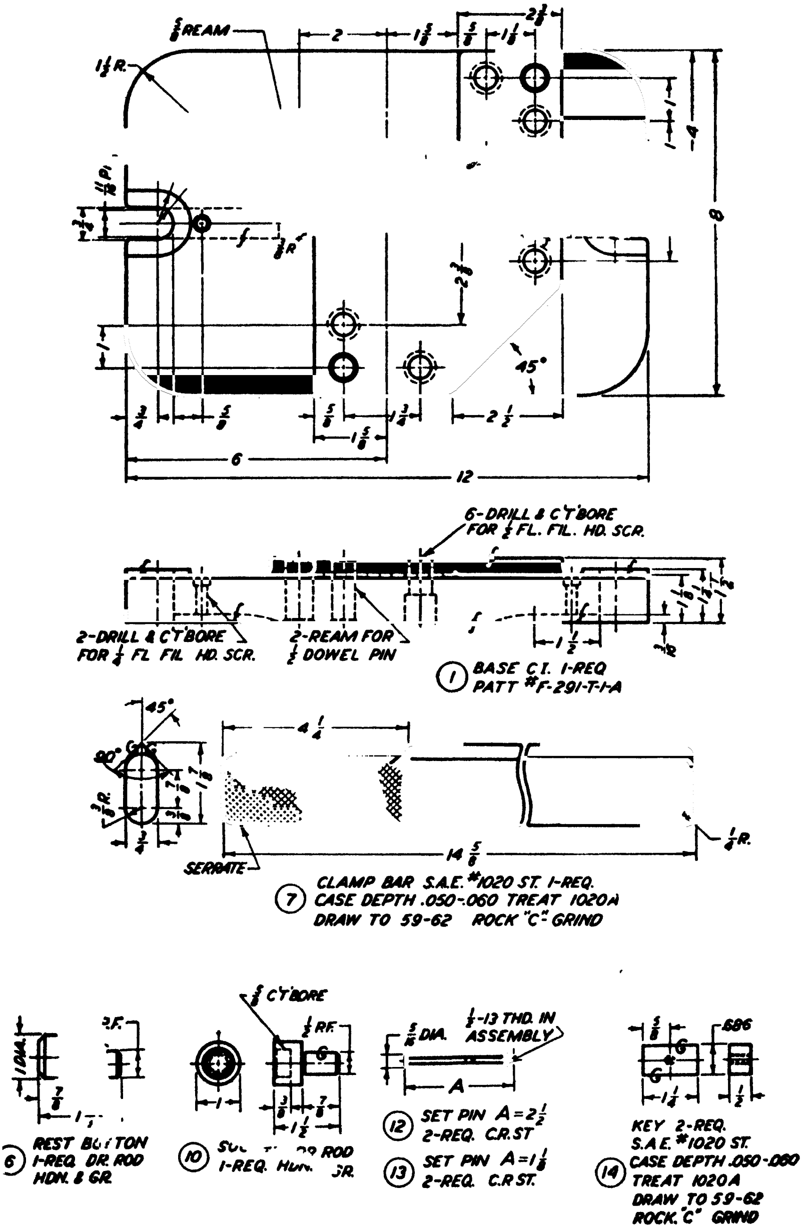

5/8 REAM
1 1/2 R.
2
1 5/8
5/8
1 1/8
2 3/8
1
4
8
2 3/8
45°
3/4
5/8
5/8
1 3/4
1 5/8
2 1/2
6
12
3/8 R
6-DRILL & C'T'BORE FOR 1/2 FL. FIL. HD. SCR.
2-DRILL & C'T'BORE FOR 1/4 FL FIL HD. SCR.
2-REAM FOR 1/2 DOWEL PIN
1 1/2
1 1/8
1 1/2
3/8
① BASE C.I. 1-REQ PATT #F-291-T-1-A
45°
90°
3/16 R.
3/4
4 1/4
14 5/8
1/4 R.
SERRATE
⑦ CLAMP BAR S.A.E. #1020 ST. 1-REQ. CASE DEPTH .050-.060 TREAT 1020A DRAW TO 59-62 ROCK "C" GRIND
1 DIA.
7/8
⑥ REST BUTTON 1-REQ. DR. ROD HDN. & GR.
3/8 C'T'BORE
1/2 RF.
1
3/8
7/8
1 1/2
⑩ 1-REQ.
5/16 DIA.
1/2-13 THD. IN ASSEMBLY
A
⑫ SET PIN A = 2 1/2 2-REQ. C.R.ST.
⑬ SET PIN A = 1 1/8 2-REQ. C.R.ST.
5/8
.686
1 1/4
1/2
⑭ KEY 2-REQ. S.A.E. #1020 ST. CASE DEPTH .050-.060 TREAT 1020A DRAW TO 59-62 ROCK "C" GRIND

Fig. 26A. Details of Fixture Shown in Fig. 25

duction-type milling machine. This design of milling fixture permits rapid loading and unloading of the piece parts.

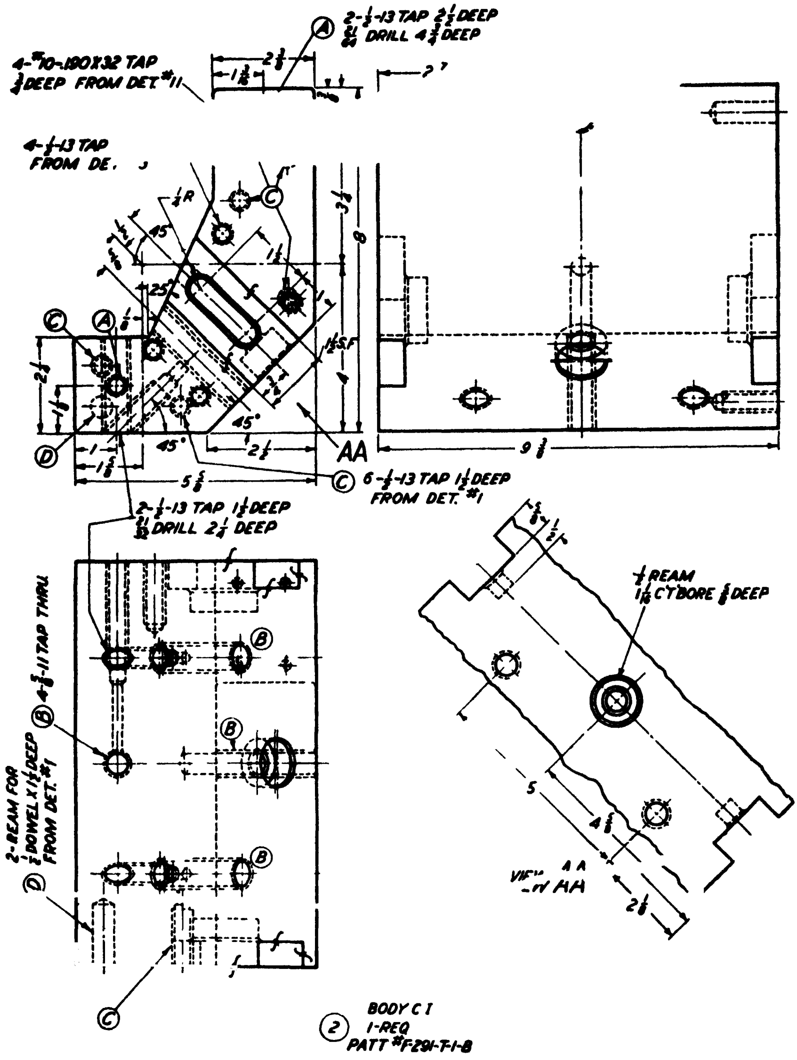


Fig 26B Details of Fixture Shown in Fi[illegible]

On high-production milling for piece parts si[illegible]ilar to Figs. 28 and 29, a magazine type of milling fixture is desi[illegible] [illegible]ause of the large quantities in which these pieces must be pr[illegible] These piece parts are used together and it is necessary that they fit each other; therefore, the same fixture is used for both parts. On one a tongue is milled, and on the other piece a slot is milled.

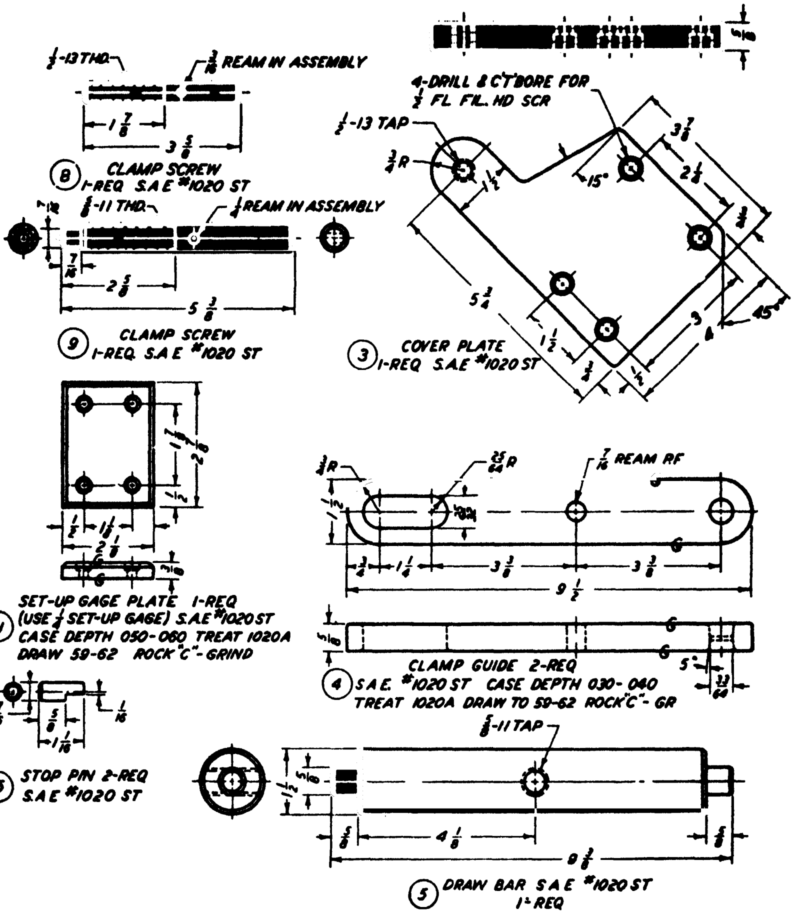

1/2-13 THD.
3/16 REAM IN ASSEMBLY
8 CLAMP SCREW 1-REQ S.A.E. #1020 ST
5/8-11 THD.
1/4 REAM IN ASSEMBLY
9 CLAMP SCREW 1-REQ. S.A.E. #1020 ST
4-DRILL & C'BORE FOR 3/8 FL FIL. HD SCR
1/2-13 TAP
3/4 R
15°
45°
3 COVER PLATE 1-REQ S.A.E. #1020 ST
11 SET-UP GAGE PLATE 1-REQ (USE 1/2 SET-UP GAGE) S.A.E. #1020 ST CASE DEPTH 050-060 TREAT 1020A DRAW 59-62 ROCK "C"-GRIND
15 STOP PIN 2-REQ S.A.E. #1020 ST
3/4 R
25/64 R
7/16 REAM RF
4 CLAMP GUIDE 2-REQ S.A.E. #1020 ST CASE DEPTH 030-040 TREAT 1020A DRAW TO 59-62 ROCK "C"-GR
5°
5/8-11 TAP
5 DRAW BAR S.A.E. #1020 ST 1-REQ

Fig 26C Details of Fixture Shown in Fig 25

Fig. 30 is an assembly drawing illustrating a top view of this fixture. Section *A-A* shows a view through the fixture. Two magazines such as the one shown in Fig. 31, are used with this fixture. Six of these piece parts can be loaded into one magazine by the operator, while the piece parts in the other magazine are being machined in the fixture. These magazines enable the operator to obtain the required production, and the design is such that the pieces are properly located by means of *V*-*blocks*.

To make sure that these parts will be in the correct location in

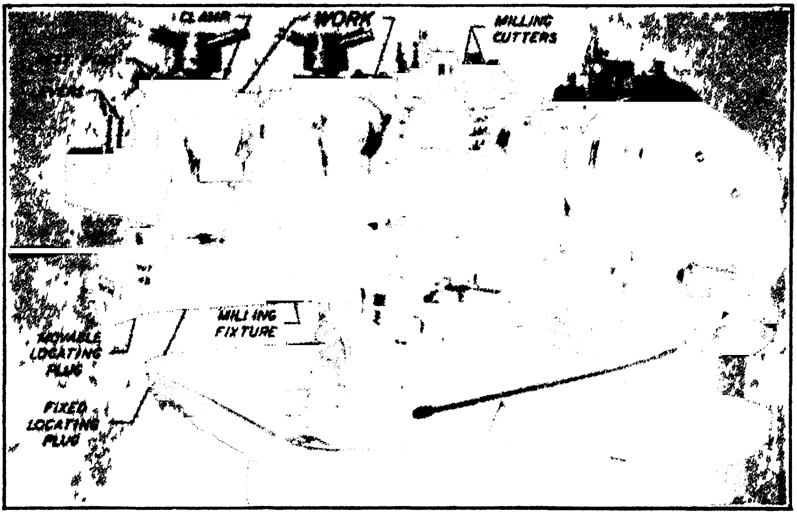


Fig 27 Fixture for Face Milling Four Gear Housings at One Time

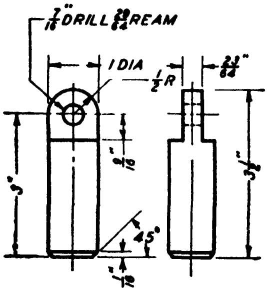


Fig 28 Piece Part to be Milled in Fixture, Fig 30

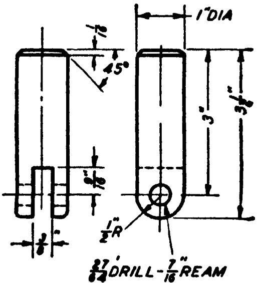


Fig 29 Piece Part to be Milled in Fixture, Fig 30

the magazine, a loading block, Fig. 32, is designed. This is made of SAE 1045 steel and is dimensioned to obtain the correct location of the piece parts The base of the fixture, Fig. 33, is designed to be made out of cast iron, as a casting for a milling fixture of this type would be less expensive than welded steel construction. It will

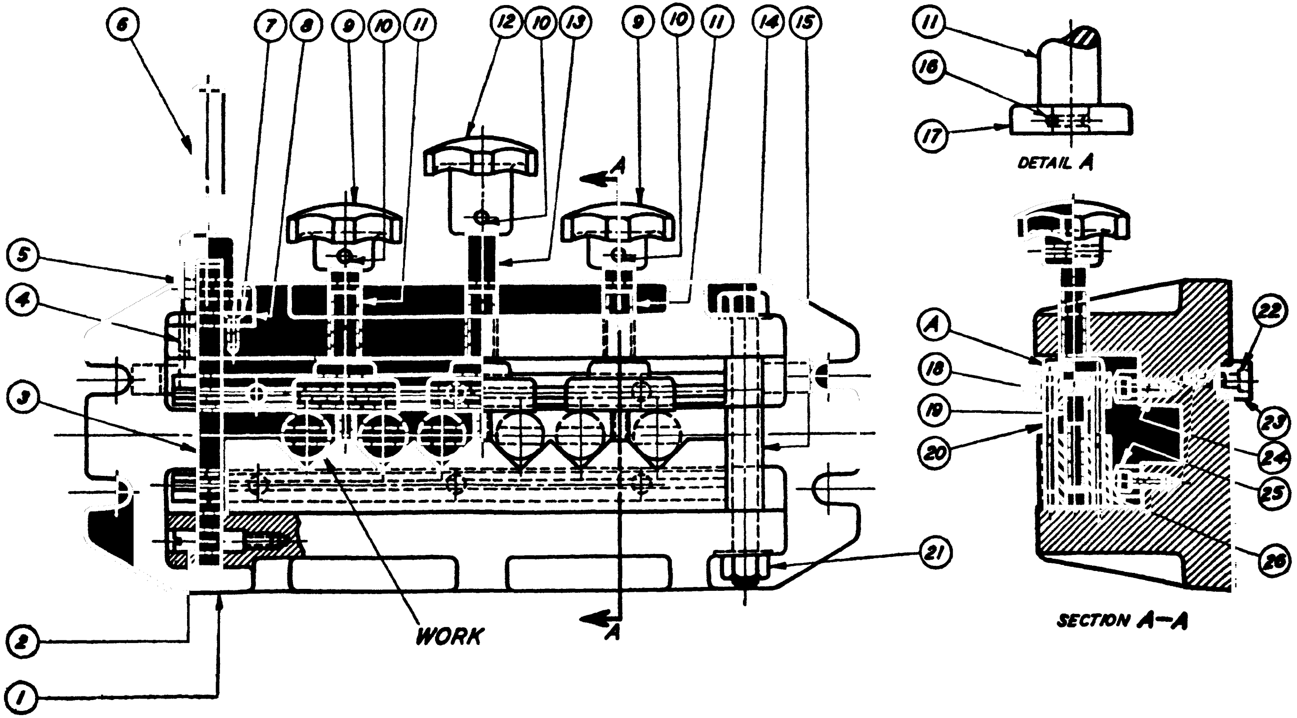


Fig. 30. High-Production Milling Fixture for Machining Tongues and Slots on Work Shown in Figs. 28 and 29

be noted that this base is machined very accurately to insure accurate work.

Other details of this fixture are shown by Fig. 34. Detail *26* is a **V**-block with six 90° vees to locate these round piece parts in the correct position. The **V**-block is the most positive way of locating round work, either in drill jigs or in any other type of fixture. Due to the fact that great quantities of pieces are to be produced with this milling fixture, this **V**-block (detail *26*) is hardened and ground to eliminate wear. The location of the other details shown in Fig. 34 can readily be identified by referring to the assembly drawing, Fig. 30.

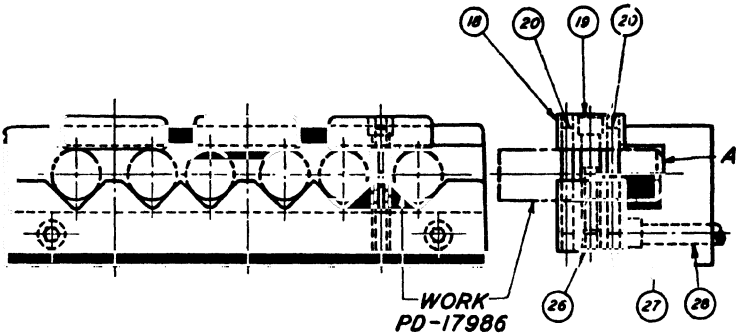


Fig. 31. Milling Fixture Magazine for Holding Work in Fixture Shown in Fig. 30

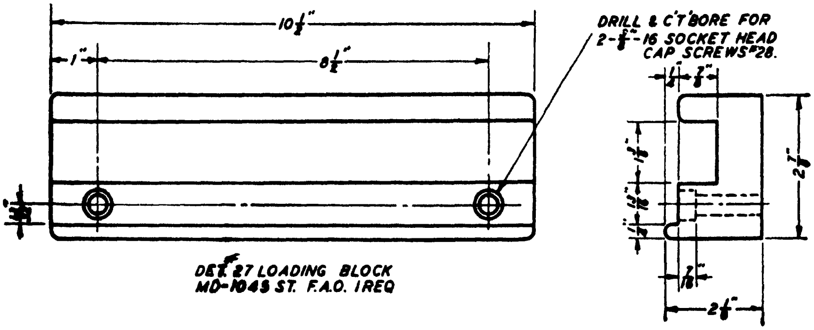

10 1/2"
1"
8 1/2"
DRILL & C'T'BORE FOR 2-3/8"-16 SOCKET HEAD CAP SCREWS #28.
1/4"
7/8"
2 7/8"
7/16"
2 1/8"
DET. 27 LOADING BLOCK
MD-10413 ST. F.A.O. 1 REQ

Fig. 32. Loading Block Used with Magazine Shown in Fig. 31

It will be noted that detail *6* of Fig. 34 is a clamp. To enable the tool room to properly make this part it is necessary to show

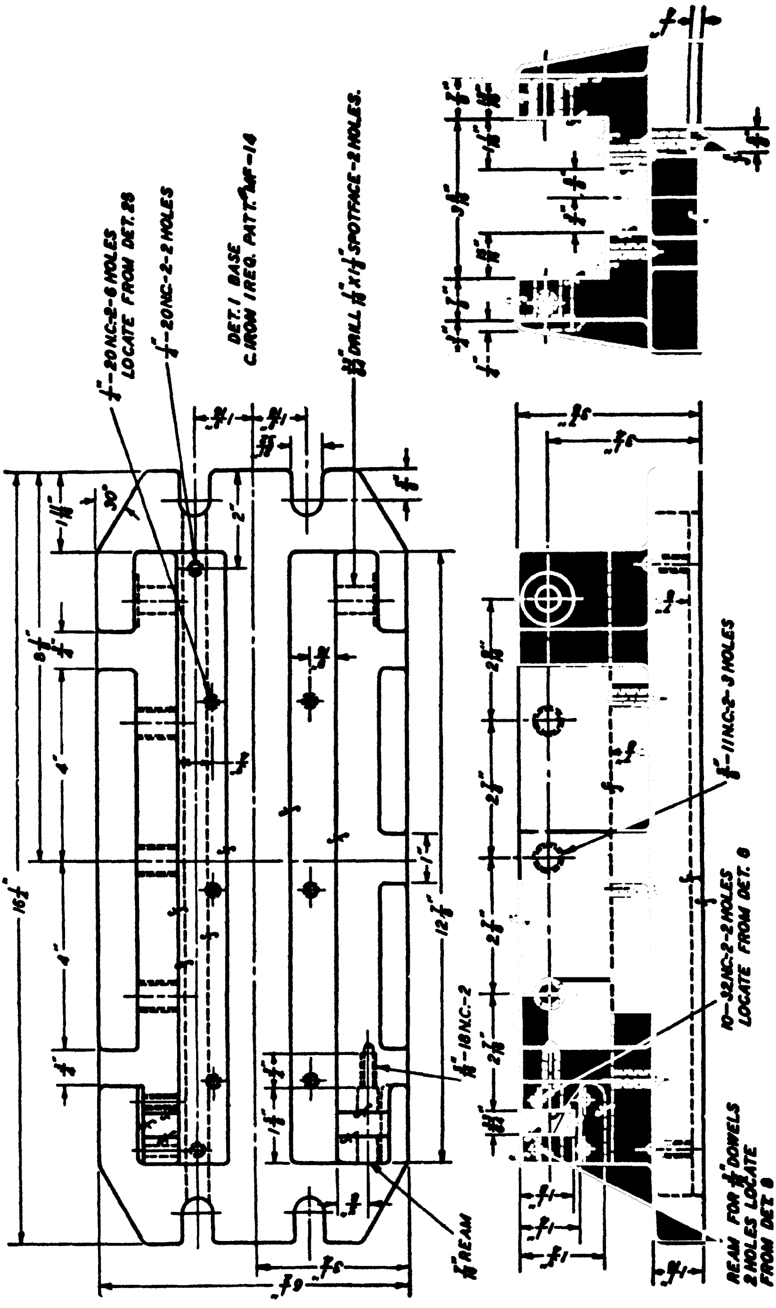

-20NC-2-6 HOLES LOCATE FROM DET. 28
-20NC-2-2 HOLES
DET. 1 BASE
C.IRON 1 REQ. PATT.
DRILL SPOTFACE-2 HOLES
16
12
30°
2"
4"
4"
-11NC-2-9 HOLES
-18NC-2
REAM
10-32NC-2-2 HOLES LOCATE FROM DET. 6
REAM FOR DOWELS 2 HOLES LOCATE FROM DET. 6

Fig. 33. Working Drawing of Base of Fixture Shown in Fig. 30

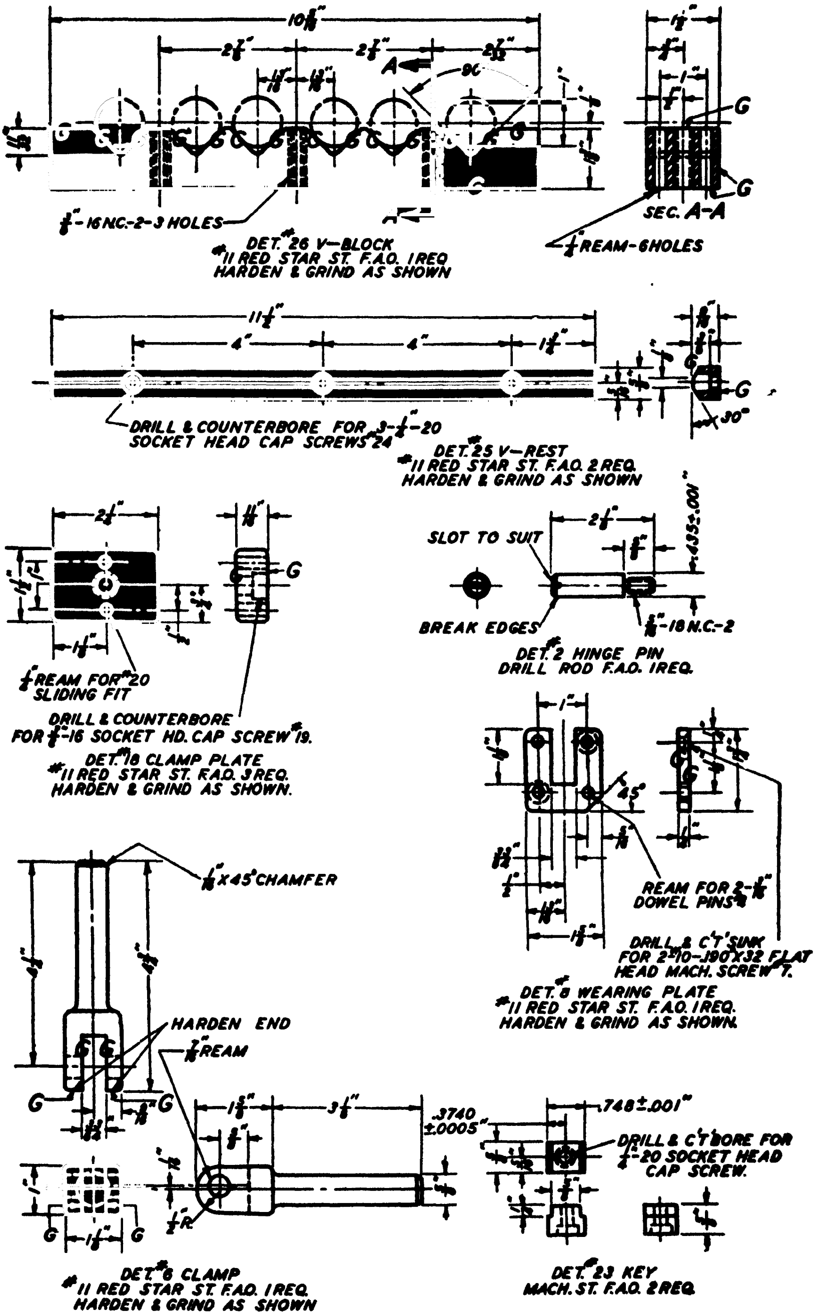
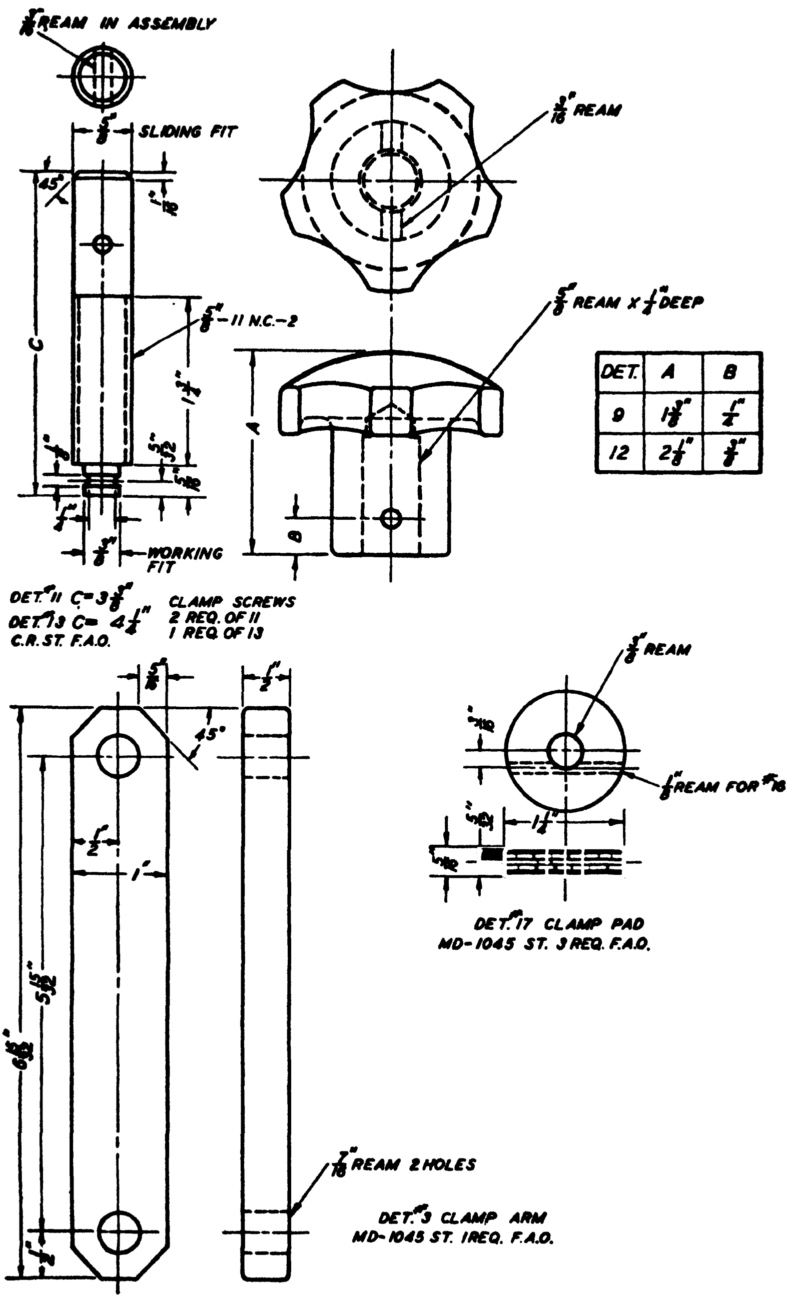


Fig. 34. Working Drawing of Parts of Milling Fixture Shown in Fig. 30



DET.	A	B
9	1 3/8"	1/4"
12	2 1/8"	3/8"

DET. #11 C = 3 5/8"
DET. #13 C = 4 1/4"
C.R. ST. F.A.O.

CLAMP SCREWS
2 REQ. OF 11
1 REQ. OF 13

DET. #17 CLAMP PAD
MD-1045 ST. 3 REQ. F.A.O.

DET. #3 CLAMP ARM
MD-1045 ST. 1 REQ. F.A.O.

Fig. 35. Clamp Screw, Knob, Clamp Arm, etc., for Fixture Shown in Fig. 3(

28	2	SOCKET HD. CAP SCREW	STANDARD	3/8"-16 N.C.-LONG TO SUIT	
27	1	LOADING BLOCK	MD-1045 ST.	2 1/8" X 2 3/8" X 10 1/2" LG.	
26	1	V-BLOCK	#11 RED STAR ST.	1 3/8" X 1 1/2" X 10 3/16" LG.	
25	2	V-REST	#11 RED STAR ST.	3/16" X 3/8" X 11 1/2" LG.	
24	6	SOCKET HD. CAP SCREW	STANDARD	1/4"-20 N.C. X 5/8" LG	
23	2	KEY	MACH. ST.	3/8" X 5/8" X 3/4" LG.	
22	2	SOCKET HD. CAP SCREW	STANDARD	1/4"-20 N.C. X 3/4" LG.	
21	1	HEXAGON NUT	STANDARD	1/2"-13 N.C.	
20	6	PIN	DRILL ROD	1/4" DIA. X 2 1/4" LG.	
19	3	SOCKET HD. CAP SCREW	STANDARD	3/8"-16 N.C. X 2" LG.	
18	3	CLAMP PLATE	#11 RED STAR ST	11/16" X 1 1/2" X 2 1/4" LG.	
17	3	CLAMP PAD	MD-1045 ST.	5/16" X 1 1/4" DIA	
16	3	CLAMP PAD PIN	C.R. ST.	1/4" DIA. X 1" LG	
15	1	SPACER	STD. PIPE	1/2" X 3 5/16" LG.	
14	1	HEX. HD. BOLT	STANDARD	1/2"-13 N.C. X 5 5/8" LG	
13	1	CLAMP SCREW	C.R. ST.	5/8" DIA. X 4 1/4" LG.	
12	1	KNOB	C. IRON		CIK-9
11	2	CLAMP SCREW	C.R. ST	5/8" DIA. X 3 3/8" LG	
10	2	KNOB PIN	C.R. ST.	3/16" DIA. X 1 1/4" LG.	
9	2	KNOB	C. IRON		CIK-9
8	1	WEARING PLATE	#11 RED STAR ST.	1/4" X 1 3/8" X 1 3/4" LG	
7	2	FLAT HD. MACH. SCREW	STANDARD	#10-32 N.C. X 3/4" LG.	
6	1	CLAMP	#11 RED STAR ST.	1" X 1 1/8" X 4 3/4" LG.	
5	1	CLAMP PIN	DRILL ROD	7/16" DIA. X 1 1/4" LG	
4	2	DOWEL PIN	STANDARD	3/16" DIA. X 3/4" LG.	
3	1	CLAMP ARM	MD-1045 ST.	1/2" X 1" X 6 13/16" LG.	
2	1	HINGE PIN	DRILL ROD	.435" DIA X 2 3/8" LG.	
1	1	BASE	C. IRON		MF-14
DET.	REQ	NAME	MATERIAL	FIN. STOCK SIZE	PATT. NO.

Fig. 36. Bill of Materials for Fixture Shown in Fig. 30

three views. The clamp is subject to considerable wear; therefore it is hardened and ground to insure accuracy and long life.

Fig. 35 illustrates additional details of this fixture, and in Fig. 36 is shown the bill of materials. These figures illustrate the proper way to make a set of tool drawings. Note that all necessary information is contained in the bill of materials, including the finished stock sizes, and the names of the details are clearly stated. This eliminates guess work and prevents misunderstanding in the tool room where the fixture is to be made. It also helps identify the various details that go into the complete milling fixture and, in the event of replacements, it is simple to specify a certain detail by name.

On high-production milling it is sometimes necessary to design and build indexing milling fixtures which allow the piece parts to be loaded and unloaded without stopping the machine. A good example of an indexing milling fixture is shown by Fig. 37. In this illustration, one side of a jaw of a wrench handle is being milled. You will note that this fixture is built with two different heights. The reason for this is that on a production-type milling machine with a milling head on either side of the table, eight piece parts (in this instance there are eight to each loading) are milled in one side and the fixture is then indexed and the other side is set so that it will mill the eight handles in the lower position in the fixture.

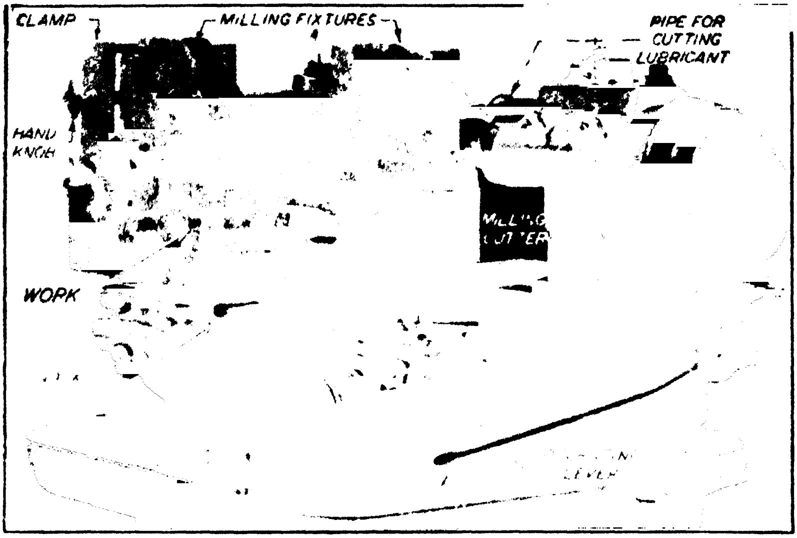


Fig. 37. Indexing Milling Fixture for Milling Wrench Handles

In milling a number of parts in a milling fixture it is necessary that the clamping be very rigid. You will note in this illustration that adequate clamping facilities have been provided. These clamps are heavy and the base of the fixture, which is made of cast iron, is very rigid due to the mass of material that has been used.

BROACHING FIXTURES

The technique and machines for broaching have been constantly improving during a period of years and at the present time the use of broaches (which are the cutting tools) and broaching fixtures is constantly increasing because broaching is one of the most accurate ways of reproducing certain dimensions in metal. Whatever accuracy is designed and built into a broach will be reproduced in the piece parts the broaches cut. On many types of work a job of broaching has proved to be faster than if the work were done with milling machine cutters and milling fixtures. For some years, limitations on broaching were due to the lack of broaching machines of suitable types. This condition has been corrected and today broaching machines are made in all types, horizontal and vertical. The size of broaching machines was also a limiting factor, but this has been changed of late years. The tool designer is frequently called on to design fixtures for these various types of broaching machines.

Broaching fixtures have a number of points in common with the design of drill jigs and milling fixtures, in that the piece parts must be located properly, and chip clearance provided as well as means for holding the work in the correct position for the broaching operation. However, on a great many piece parts that are broached, the simplest types of fixtures can be designed. In some instances no fixtures are necessary; for example, in broaching bronze bushings. They are just held against the face plate and the broach is pulled through, as the design of the broach is such that it tends to center the work properly.

Fixtures for Keyway Broaching. The simplest form of broaching is machining keyways in gears, and the bores of pulleys and bushings. Fig. 38 is a design of a simple keyway broaching fixture. This consists of a round steel flange that is drilled and counterbored for socket-head cap screws which attach this flange to the face of the broaching machine. In addition, two holes for ½″ dowel pins are drilled and reamed in this flange. A plug, approximately the same diameter as the bore of the gear, is designed as part of the fixture and a keyway is machined into the plug and through the rest of the fixture as shown, so that when the spur gear is mounted over the plug, and the keyway broaching bar is inserted into the pull head of the broaching machine, the keyway in the gear will be cut by pulling the broach through the gear that is mounted on the broaching fixture. These types of fixtures are sometimes termed work supports. In this piece part the location of the keyway is not important, therefore it is not necessary to locate the gear in any particular place on the face of the broaching fixture.

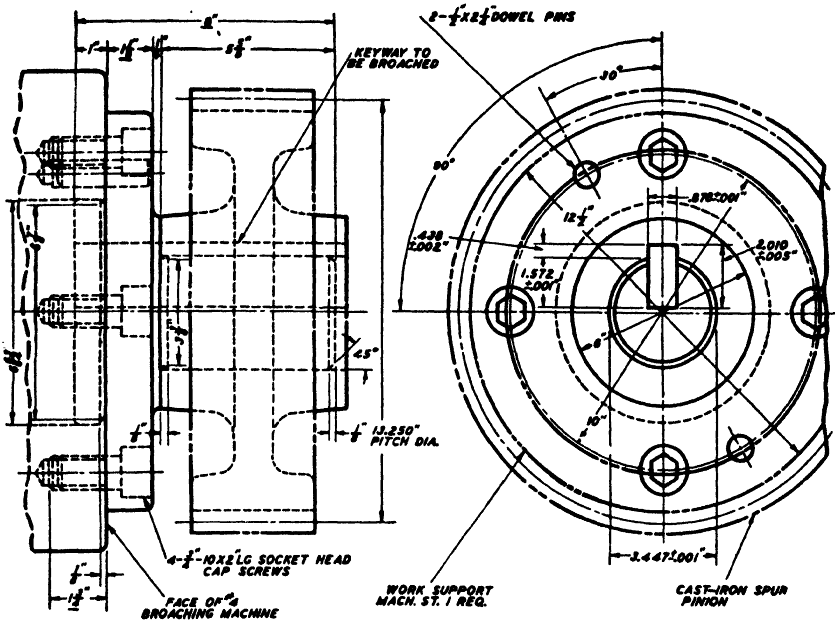
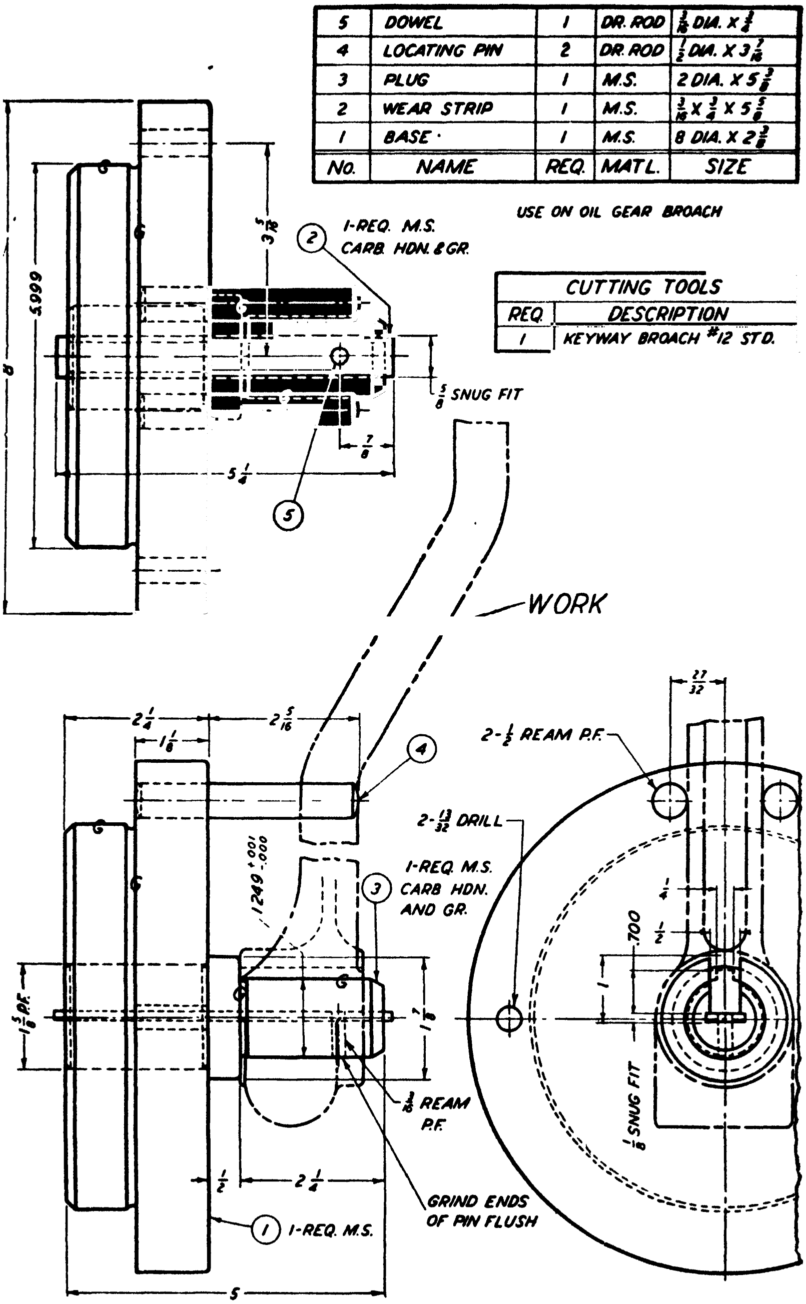


Fig. 38. Spur Gear Mounted in Broaching Fixture Ready for Cutting Straight Keyway

Where it is necessary to broach a keyway in a certain location in a piece part, a broaching fixture similar to Fig. 39 is designed. In this case the fixture is somewhat similar to that shown in Fig. 38, except that there are two locating pins (detail *4*) mounted on the face plate (*1*) of this fixture to hold the work piece in definite relation so that the keyway will be broached in the proper position.

This fixture is used for high production; therefore, hardened and ground wear strip (detail *2*) is provided. This consists of a



No.	NAME	REQ.	MATL.	SIZE
5	DOWEL	1	DR. ROD	$\frac{3}{16}$ DIA. X $\frac{3}{4}$
4	LOCATING PIN	2	DR. ROD	$\frac{1}{2}$ DIA. X $3\frac{7}{16}$
3	PLUG	1	M.S.	2 DIA. X $5\frac{3}{8}$
2	WEAR STRIP	1	M.S.	$\frac{3}{16}$ X $\frac{3}{4}$ X $5\frac{5}{8}$
1	BASE	1	M.S.	8 DIA. X $2\frac{3}{8}$

USE ON OIL GEAR BROACH

CUTTING TOOLS

REQ.	DESCRIPTION
1	KEYWAY BROACH #12 STD.

Fig. 39. Fixture to Broach Keyway in a Certain Location in the Piece Part

piece of flat machine steel that is carburized, hardened and ground. The back of the keyway broaching bar rests on this strip. This prevents wear and maintains accuracy.

Detail *3* is a plug that is also hardened and ground, and it will be noted that this is a combination locating plug and rest pad. It is designed to be made with a shoulder so that the face of the work will rest against the hardened shoulder. The keyway is machined in this plug and through the base of the fixture so that the broaching bar can be inserted through the fixture and through the pull head of the broaching machine in order to broach the keyway in the piece part. This design is for broaching keyways on horizontal pull-type broaching machines.

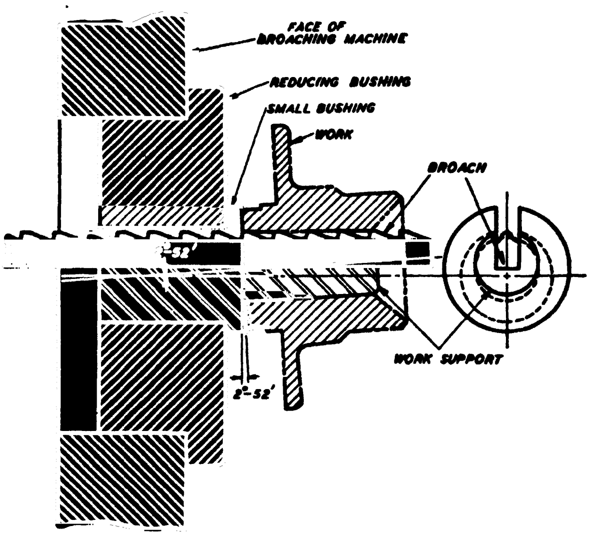


Fig. 40. Bushing Mounted in Broaching Fixture for Cutting Taper Groove

On certain types of piece parts it is necessary to have a taper keyway in order to mount the piece part on a shaft that is also tapered. It is also necessary at times to broach taper grooves in bushings. To do a job of this kind, a taper groove or keyway broaching fixture similar to Fig. 40 is designed. Due to the design of the face of the broaching machine, the reducing bushing is turned so that a shoulder is created, and this is attached to the face of the broaching machine in the usual manner. The locating plug is inserted in the reducing bushing. The locating portion of this plug is turned on an angle that will correspond with the angle to which the

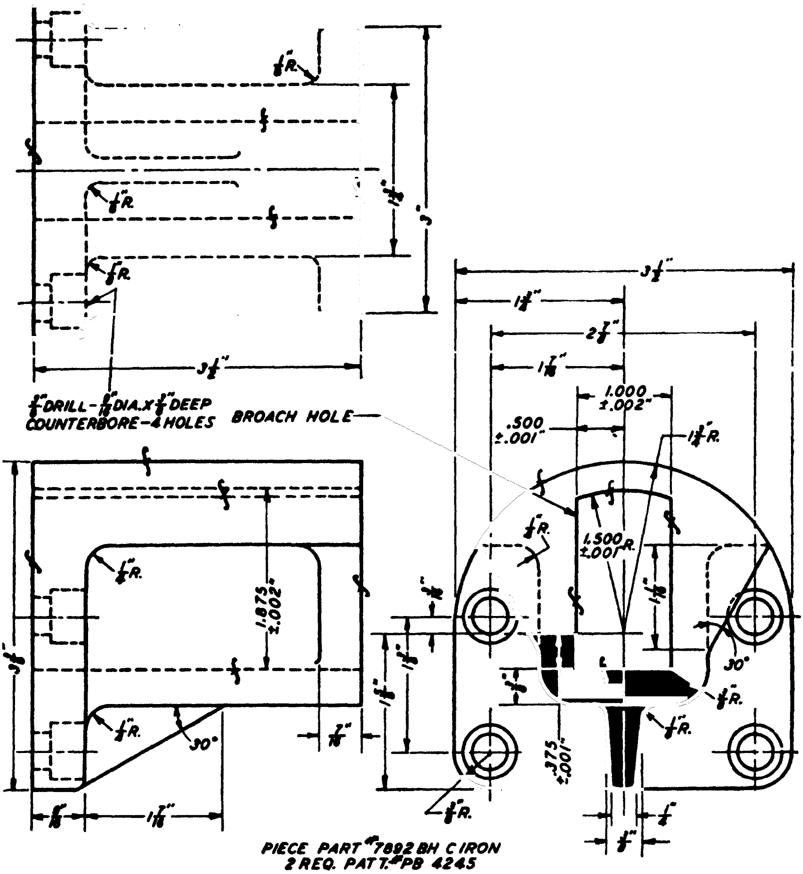


Fig. 41. Production Drawing of Piece Part Broached in Fixture Shown in Fig. 42

taper keyway or groove is to be broached. In this case this angle is 2 degrees 52 minutes. The locating plug is tapered so that when the work piece is mounted on the locating plug and the straight broach is pulled through the work, it will cut this taper groove to the correct angle.

Fixtures for Broaching a Rectangular Hole. To broach a rectangular hole in a piece part similar to Fig. 41 in which the rectangular hole extends through the part and must be in definite relation to other dimensions, a broaching fixture similar to Fig. 42 is designed. Due to the shape of the piece part it is necessary to provide clamping means on the broach fixture. By referring to Fig. 42 it will be seen that a swinging hinged clamp (*3*) is provided.

The fixture body (*1*) is somewhat similar to those already described except for the supporting brackets shown by Fig. 43. This body is a gray iron casting that is designed to locate and hold the piece part in the correct position. A hardened and ground wear plate (detail *2*) is designed to be made of tool steel so that the back of the rectangular broach will slide on this wear plate and prevent the teeth from destroying the accuracy of the fixture.

Fig. 44 illustrates the design of the face plate (*5*), the clamp (*3*), and the clamp screw (*4*). Referring again to Fig. 42, the locations of these details are shown in the assembly drawing. The lower left-hand corner shows a sectional view of this fixture mounted to the face plate of a broaching machine.

Fixtures for Broaching Serrations. For high-production broaching for an item like a pipe wrench that has a series of serrated teeth in it to hold the pipe and to grip it securely, it is necessary either to mill or to broach these teeth. Formerly milling cutters were used to cut them, but at the present time the teeth are machined in these handles and in jaw ends of pipe wrenches by means of broaches and broaching fixtures. For a job of this kind, a broaching fixture similar to that shown in Fig. 45 is designed. This fixture has been designed so that two pipe-wrench handles can be loaded at one time. As will be seen from this drawing, the fixture consists of a base plate that is mounted in the face of the broaching machine, and a hardened and ground locating gage block (*6*) is attached to the fixture by means of flat-head machine screws (*5*).

The wrench handle is machined on the sides so that when the pieces are loaded in the fixture there will be no unevenness and no rocking of the piece part. Hardened and ground wear plates (details *4* and *11*) are provided to guide the broaching bar. It is not necessary to clamp these parts in the fixture because of the fact that the piece part fits in on the gage blocks in the proper position and the pulling action of the broach tends to hold these pieces securely in place

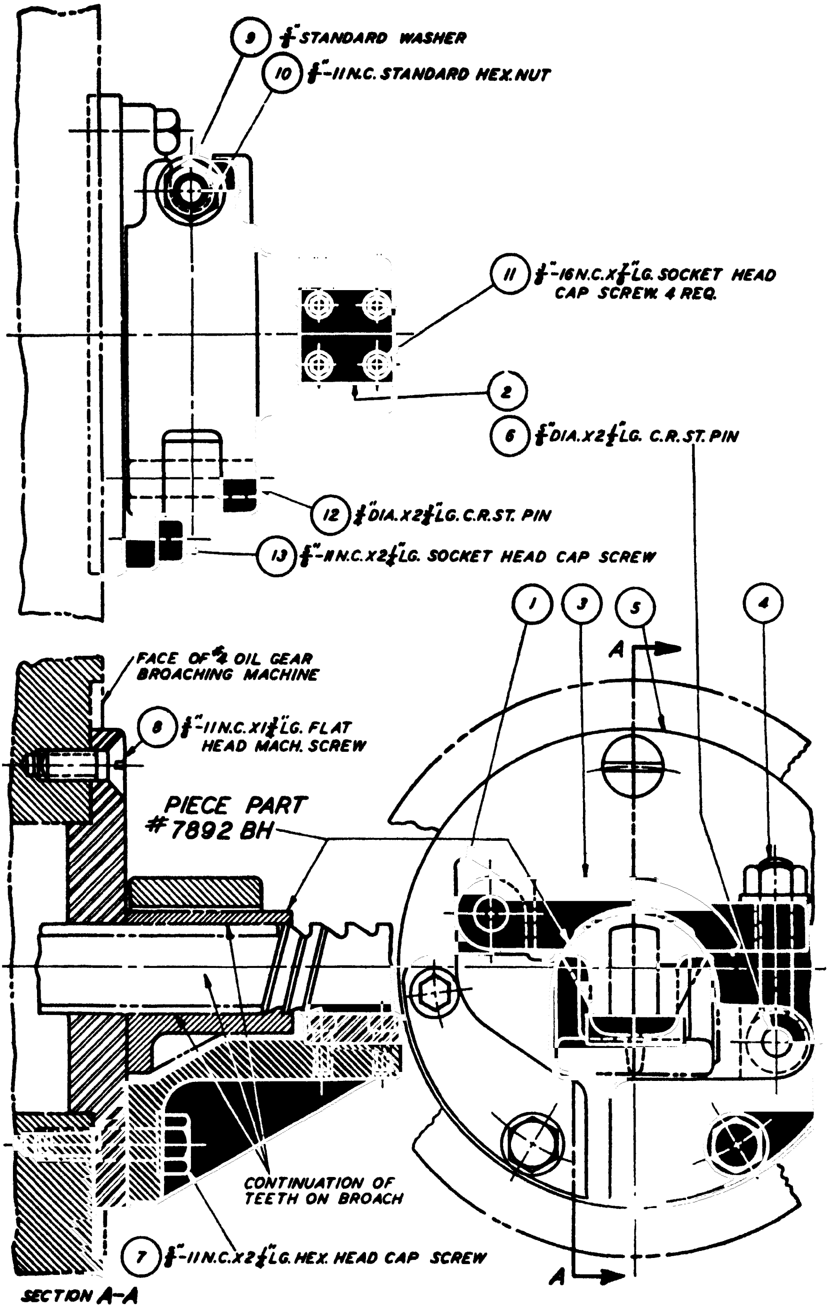

9 5/8" STANDARD WASHER
10 5/8"-11 N.C. STANDARD HEX. NUT
11 3/8"-16 N.C. X 7/8" LG. SOCKET HEAD CAP SCREW. 4 REQ.
2
6 5/8" DIA. X 2 1/2" LG. C.R. ST. PIN
12 1/2" DIA. X 2 1/4" LG. C.R. ST. PIN
13 5/8"-11 N.C. X 2 1/4" LG. SOCKET HEAD CAP SCREW
1
3
5
4
A
FACE OF #4 OIL GEAR BROACHING MACHINE
8 5/8"-11 N.C. X 1 1/2" LG. FLAT HEAD MACH. SCREW
PIECE PART #7892 BH
CONTINUATION OF TEETH ON BROACH
7 5/8"-11 N.C. X 2 1/4" LG. HEX. HEAD CAP SCREW
A
SECTION A-A

Fig. 42. Piece Part Clamped in Broaching Fixture for Cutting Rectangular Hole

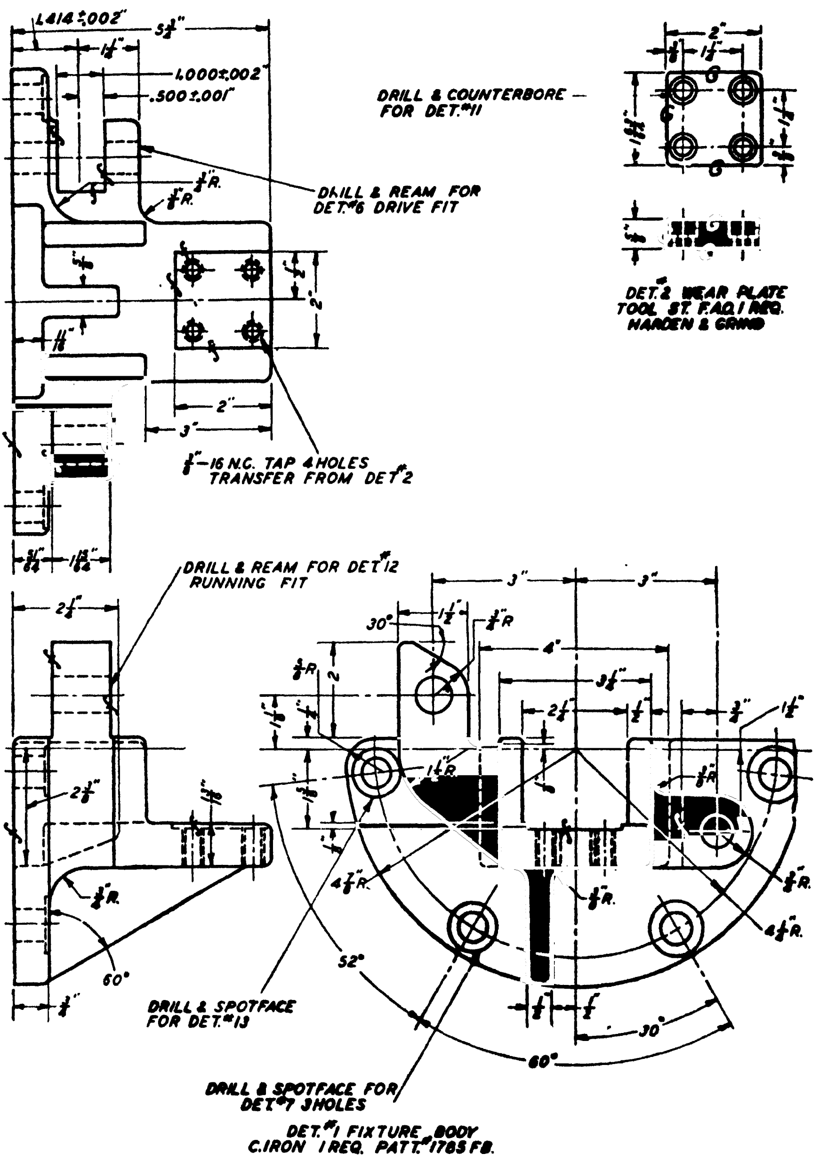
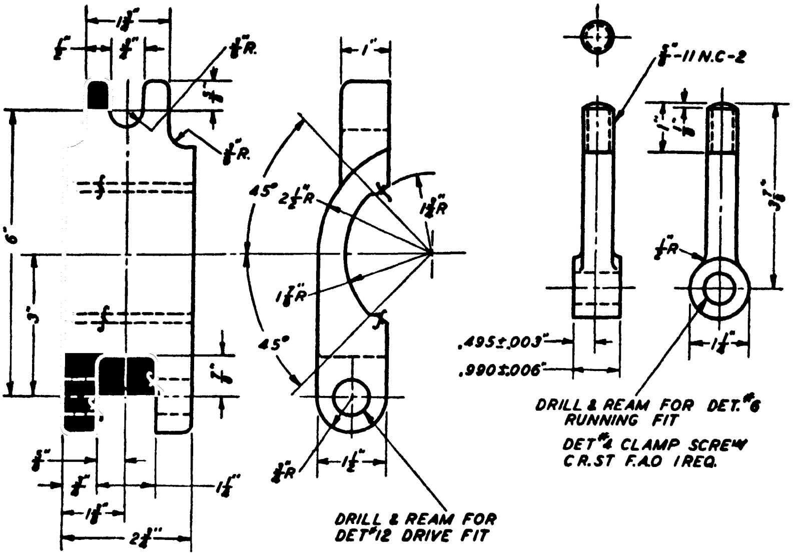

1.414±.002"
5¼"
1¼"
1.000±.002"
.500±.001"
DRILL & COUNTERBORE — FOR DET.#11
DRILL & REAM FOR DET.#6 DRIVE FIT
¾"R.
¾"R.
2"
2"
3"
¼"-16 N.C. TAP 4 HOLES TRANSFER FROM DET.#2
2"
1½"
G
DET.#2 WEAR PLATE TOOL ST. FAO. 1 REQ. HARDEN & GRIND
DRILL & REAM FOR DET.#12 RUNNING FIT
2¼"
2¼"
3"
3"
30°
1½"
¾"R
4"
3¼"
2¼"
½"
¾"
1¼"
1½"R
¾"R
4¼"R
¾"R.
¾"R.
4¼"R.
60°
52°
30°
60°
DRILL & SPOTFACE FOR DET.#13
DRILL & SPOTFACE FOR DET.#7 3 HOLES
DET.#1 FIXTURE BODY C.IRON 1 REQ. PATT.#1785 FB.

Fig. 43. Working Drawings of Broaching Fixture Shown in Fig. 42

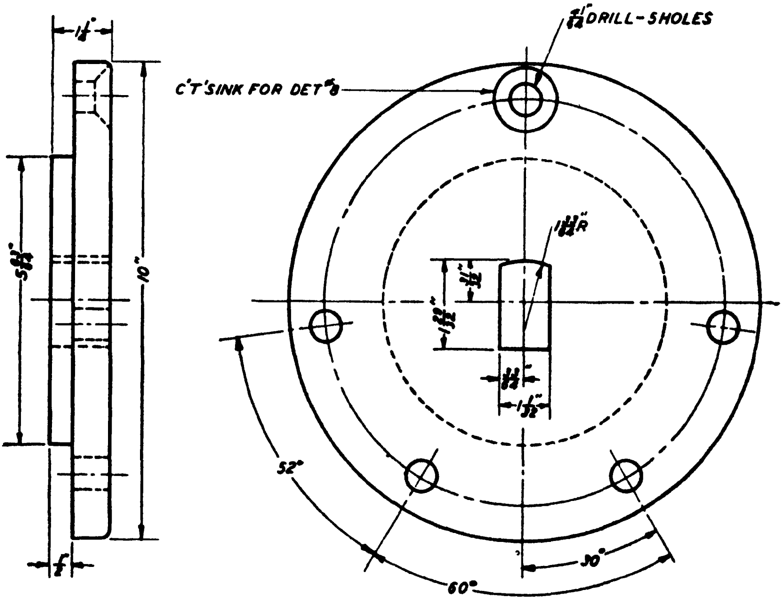
To design a fixture for the jaw end of a pipe wrench, a fixture such as the one shown in Fig. 46 is designed. It will be seen that, due to the shape of the piece part, it is necessary to provide clamping



6"
3"
45°
2½"R
1⅜"R
1⅛"R
45°
1"
1½"
1¼"
2¼"
.495±.003"
.990±.006"
⅜"-11 N.C-2
3⅞"
DRILL & REAM FOR DET.#6 RUNNING FIT
DRILL & REAM FOR DET#12 DRIVE FIT

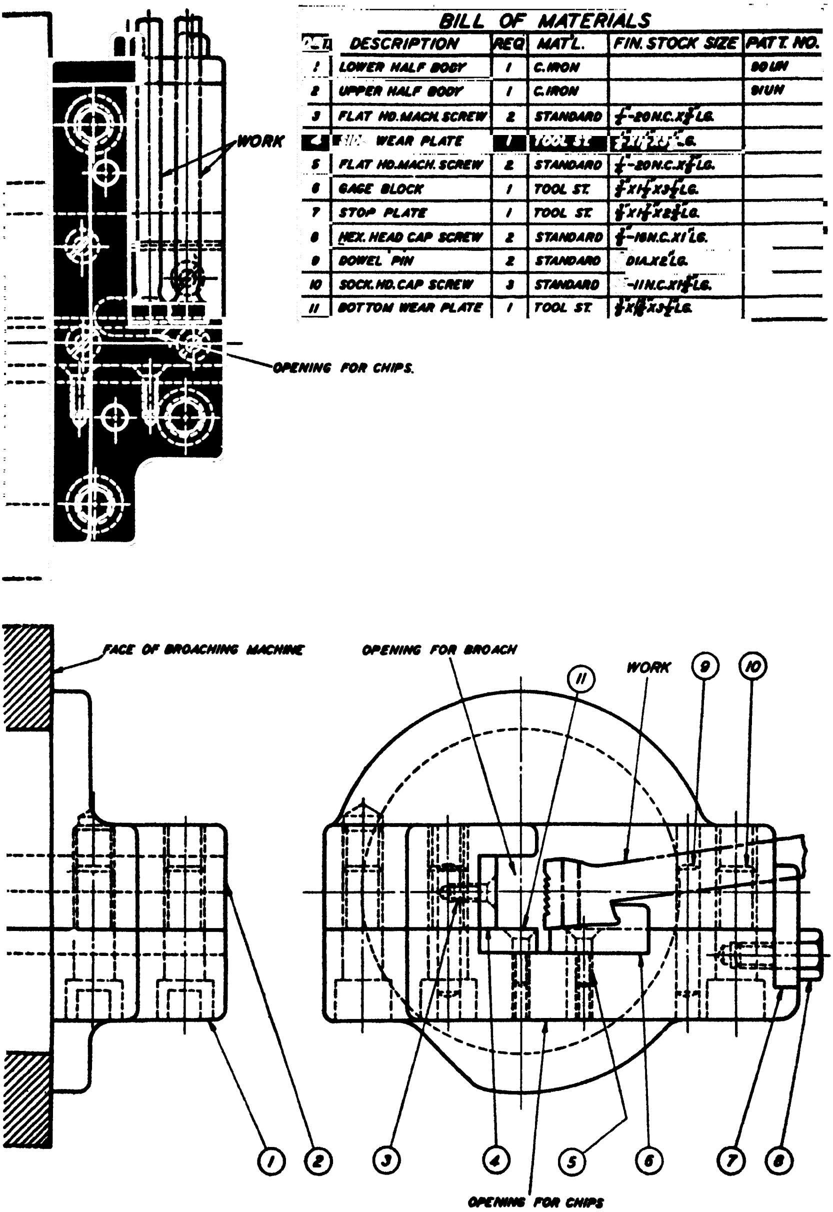
DET#4 CLAMP SCREW
C.R.ST F.A.O 1 REQ.

DET#3 FIXTURE CLAMP
C IRON 1 REQ. PATT.#1786 FB



DET#5 FACE PLATE
C.R.ST F.A.O. 1 REQ.

Fig. 44. Working Drawings of Broaching Fixture Shown in Fig 42



BILL OF MATERIALS

DET.	DESCRIPTION	REQ	MAT'L.	FIN. STOCK SIZE	PATT. NO.
1	LOWER HALF BODY	1	C. IRON		90 UN
2	UPPER HALF BODY	1	C. IRON		91 UN
3	FLAT HD. MACH. SCREW	2	STANDARD	¼"-20N.C.X⅝"LG.	
4	SIDE WEAR PLATE	1	TOOL ST.	[illegible] LG.	
5	FLAT HD. MACH. SCREW	2	STANDARD	¼"-20N.C.X⅝"LG.	
6	GAGE BLOCK	1	TOOL ST.	⅝"X1½"X3½"LG.	
7	STOP PLATE	1	TOOL ST.	⅝"X1½"X2½"LG.	
8	HEX. HEAD CAP SCREW	2	STANDARD	⅜"-16N.C.X1"LG.	
9	DOWEL PIN	2	STANDARD	DIA.X2"LG.	
10	SOCK. HD. CAP SCREW	3	STANDARD	-11N.C.X1½"LG.	
11	BOTTOM WEAR PLATE	1	TOOL ST.	⅝"X⅜"X3½"LG.	

Fig. 45. Broaching Fixture Showing Two Pipe-Wrench Handles which Are Machined in One Stroke of the Broach

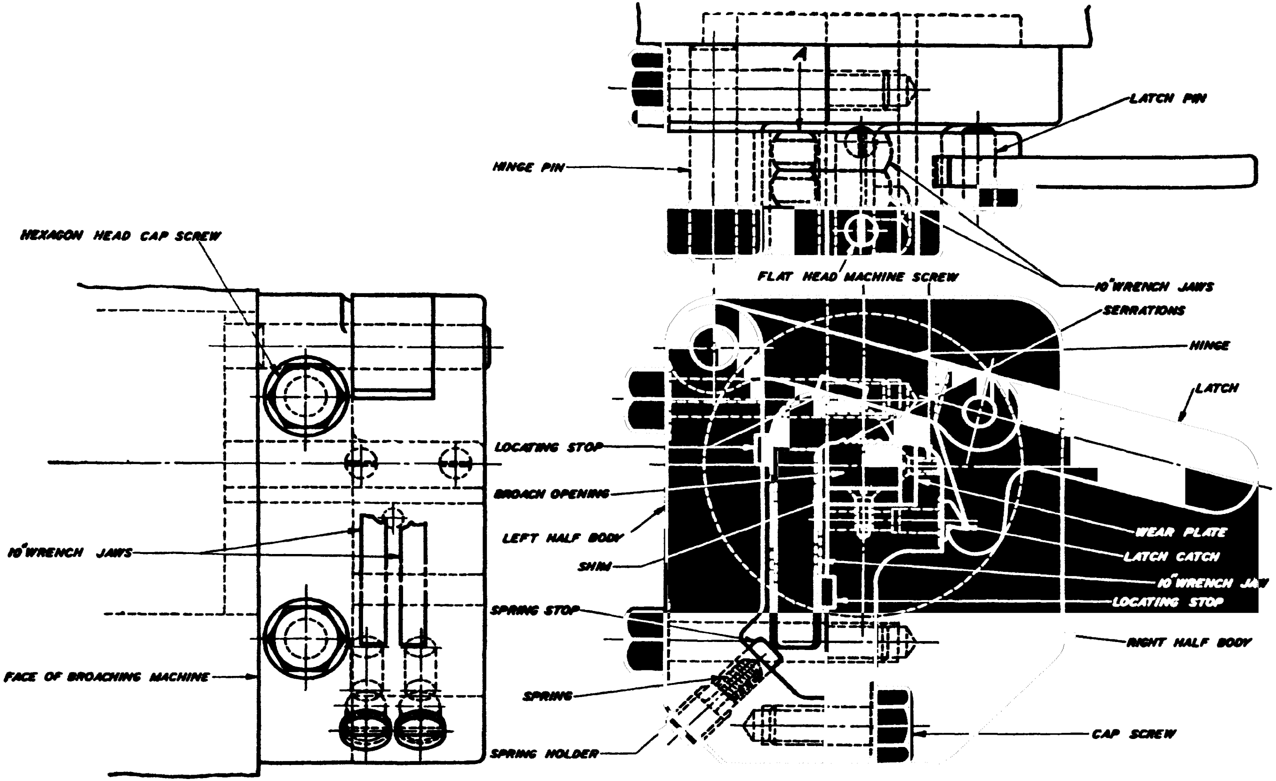


Fig. 46. Broaching Fixture Showing Two Pipe-Wrench Jaw Ends which Are Machined in One Stroke of the Broach

means. In this fixture, two pipe-wrench jaws are broached at one time. The clamping means is a latch type clamp that holds the piece part securely in the fixture. Hardened and ground locating stops are provided so that there will be no excessive wear of the fixture due to the loading and unloading of a large number of piece parts

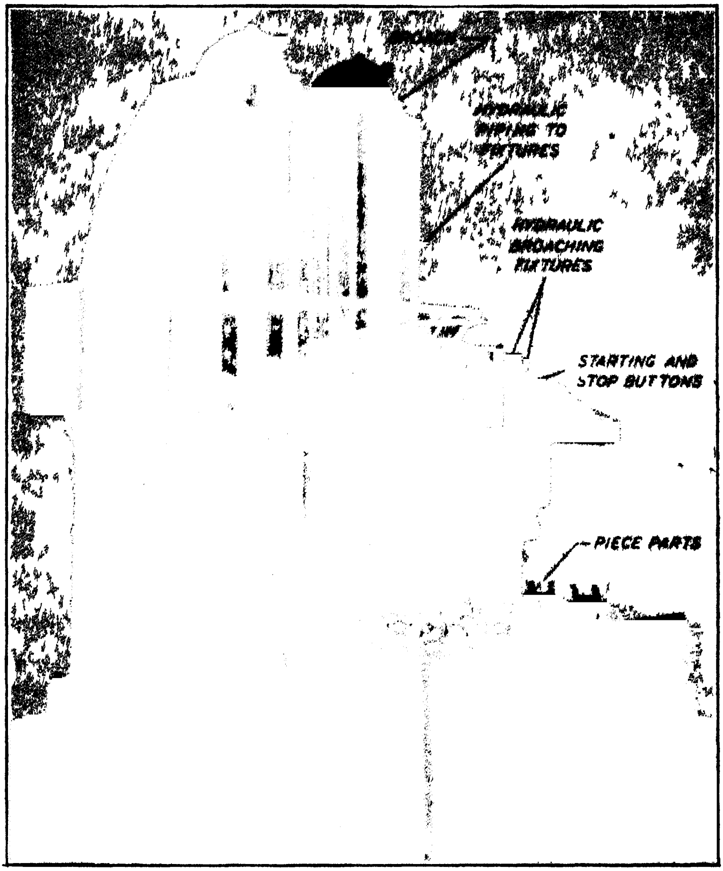

HYDRAULIC PIPING TO FIXTURES
HYDRAULIC BROACHING FIXTURES
STARTING AND STOP BUTTONS
PIECE PARTS

Fig 47 Double-Spindle Hydraulic Vertical Broaching Machine Equipped with Hydraulically Operated Broaching Fixtures

Fixtures of Broaching on High-Production Work. On a great many broaching operations in automobile plants, due to the very large number of parts that are to be produced (such as parts for universal joints for the drive shaft of an automobile) the fixtures *are sometimes very elaborate. Fig. 47 is an illustration showing* hydraulic broaching fixtures for performing several operations on parts of a universal joint. The piece parts are shown at the front of this machine. They go through a succession of broaching operations and are completely broached at the end of the work cycle. Broaching machines of this type are used largely in high-production manufacturing plants.

BORING FIXTURES

In designing boring fixtures, as in the designing of drill jigs, the accuracy of the part to be produced depends upon the accuracy that is designed and built into the fixture. There are almost as many types of boring fixtures as there are types of drill jigs; therefore the details of boring fixture design will not be discussed or shown at any great length in this book on account of space limitations. The tool designer must keep in mind certain important points in boring fixture design, and these are identical with those given in the section of this book on drill jig design.

There are a great many boring operations performed on certain classes of work where fixtures are not used because of the small quantity produced. Such jobs are usually done in horizontal boring machines. The bar is then guided in the outer bearing bracket of the boring machine. There is one very important point for the tool designer to bear in mind when designing boring fixtures where guide bushings are to be used; that is, that the length of the guide bushings must be at least one and one-half times the diameter of the boring bar that will be used in the fixture. For example, if a 2″ boring bar is to be used to machine the work piece, the guide bushing for this boring bar should be at least 3″ long. In many plants it is considered good practice to have the length of the guide bushing double the diameter. In other words, if a 2″ bar is used, the guide bushing will be 4″ in length. If the tool designer will keep in mind the fact that boring is somewhat similar to operations performed in drill jigs, he should have no great difficulty in designing boring fixtures.

Fixtures for Boring Cylinder Blocks. Fig. 48 illustrates a boring fixture designed for use in machining the cylinder bores in an engine block. This fixture consists of a cast-iron base that has a separate bushing plate mounted on the top of it by means of hex-

agon-head screws, and with dowel pins to locate it properly. Four hardened and ground steel bushings are inserted in this bushing plate to guide the boring bars in the correct position. Locating pins and rest pads are provided in the base of this fixture, and the 4-cylinder block can be clamped in the fixture by means of the steel clamps on either side of the fixture. In this design of fixture the boring bars are guided on the top end only; therefore, these bushings are made

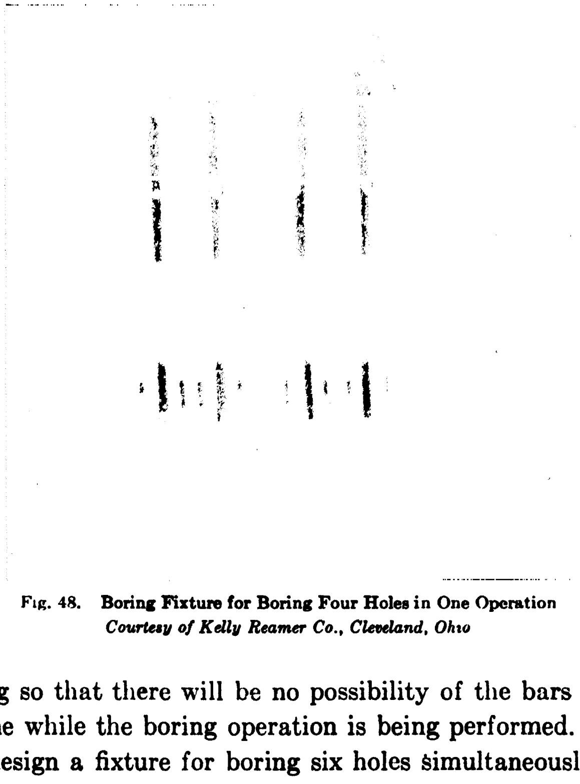


Fig. 48. **Boring Fixture for Boring Four Holes in One Operation**
Courtesy of Kelly Reamer Co., Cleveland, Ohio

extra long so that there will be no possibility of the bars springing out of line while the boring operation is being performed.

To design a fixture for boring six holes simultaneously in a 6-cylinder automobile block, a fixture similar to Fig. 49 would be designed. This fixture has pilot bushings at top and bottom to insure positive alignment of the boring bars in the fixture. In the bushing plate in this boring fixture, hardened and ground liner bushings are provided to receive the pilot bushings that are inserted on the shank end of the boring bar. The pilot bushings on the boring bars themselves are larger than the diameter of the bore. This is necessary by reason of the fact that it would be impossible to have the bars guided properly unless the bushings *could hold the boring bars in positive* alignment, and due to the diameter of the bore it would be necessary to make the shank diameters of these bars quite large. This would be a useless waste of material and would add excessive weight to the sliding head of the vertical type boring machine that is used for this job.

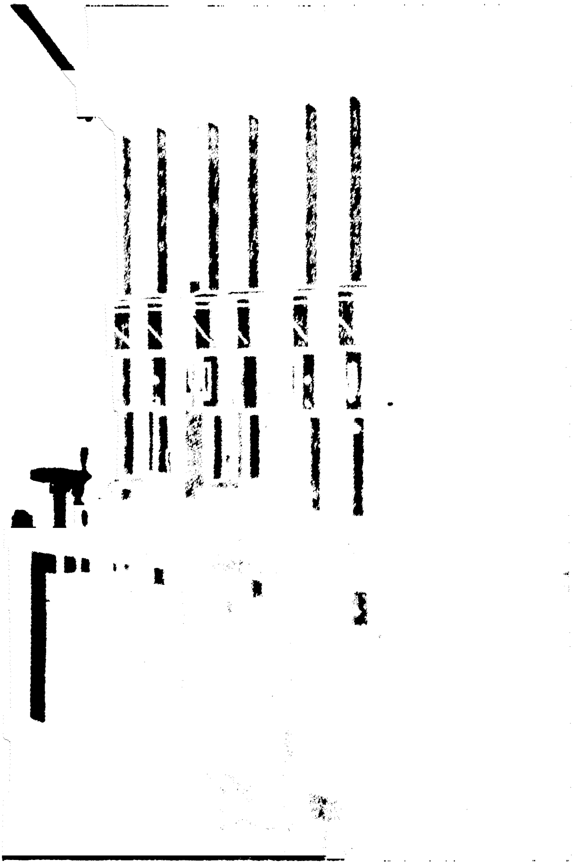


Fig. 49. Boring Fixture for Boring Six Holes in One Operation
Courtesy of Kelly Reamer Co., Cleveland, Ohio

Fixtures for Double-End Boring Machines. On high-production boring of automobile and tractor parts, special double-end boring machines are employed. Fig. 50 illustrates a double-end boring machine with a vertical spindle for boring a hole in the top

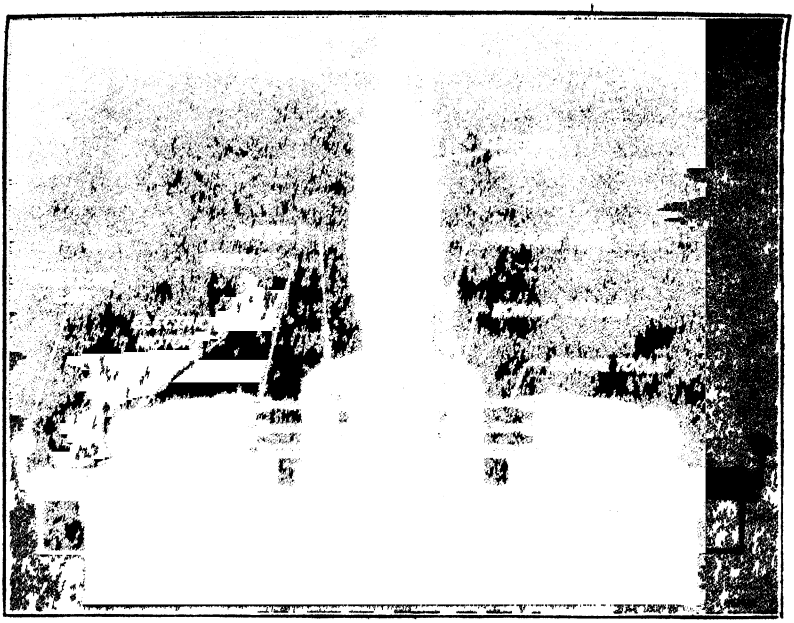


Fig 50 Three-Way Hydraulically Operated Boring Machine

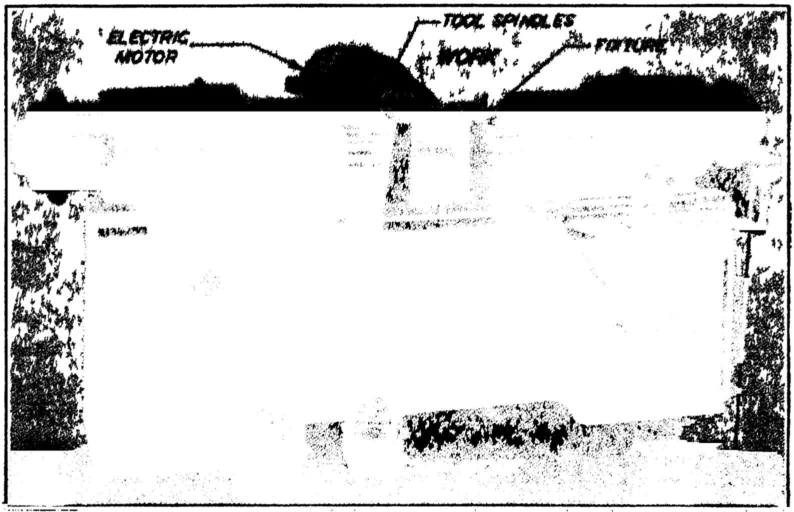


Fig. 51. Three-Way Horizontal Drilling and Boring Machine

of a piece part. This fixture is provided with guide bushings on either end, and the boring bars are made with hardened and ground wear strips to prevent wear and insure accuracy. This fixture is so large that eyebolts are provided so it can be removed readily from the machine by means of a crane. This machine has multiple horizontal spindle heads on either end, and one vertical spindle head. The heads are all operated by means of hydraulic cylinders.

Fixtures for Horizontal Boring Machines. To bore transmission housings, 3-way horizontal boring machines are used. Fig. 51 shows a machine of this type with a fixture mounted in the center. This fixture, as will be noted, is very simple and consists of a box-type casting in which the piece part is located by means of locating pins. It is set on rest pads and clamped in position by means of the screw clamp. The photograph also shows two of these piece parts in the immediate foreground of the machine. This is also a hydraulic machine; the three heads traverse in and out by means of hydraulic pressure. Stops are provided on the machine so that these heads will travel only to a certain position and are then reversed. While in this case the machine is somewhat complicated, the fixture is very simple, which is always considered good design practice.

GRINDING FIXTURES

Grinding operations are becoming more important in modern metal-manufacturing plants due to the fact that a great many parts that were formerly left soft are now hardened and ground to the finished dimensions. In addition, a great number of gears that were formerly left soft are now hardened, and this means that they must be ground on certain sections in order to obtain the required accuracy.

To perform many of these grinding operations it is necessary to design grinding fixtures. A great many production parts can be ground, without the use of fixtures, in machines such as surface grinders. These are of two types: either wet or dry. A wet surface grinder is one having a coolant tank and pump mounted in the base of the machine. The coolant, as it flows over the work, removes the waste material and the fine grit from the grinding wheel.

Fixtures for Use in Surface Grinding. Fig. 52 is a bearing spacer. It will be noted from the drawing that it is ground on both ends. Being a circular piece, it would be expensive to grind this in an ordinary cylindrical grinder; therefore it was decided that this piece should be ground in a vertical grinding machine. This type of machine has a magnetic chuck that revolves, and a vertical spindle with a grinding wheel mounted on it in a horizontal position. The chuck revolves in one direction and the grinding wheel in the opposite direction. Therefore it was decided to use a grinding fixture, Fig. 53. As will be noted from the drawing, this fixture is designed to be made of SAE 1020 steel ⅛″ thick. Two pieces of this material are used, rolled into an inner and outer ring. Stiffener pieces (detail *3*) are used to tie the inner (*2*) and the outer (*1*) rings together.

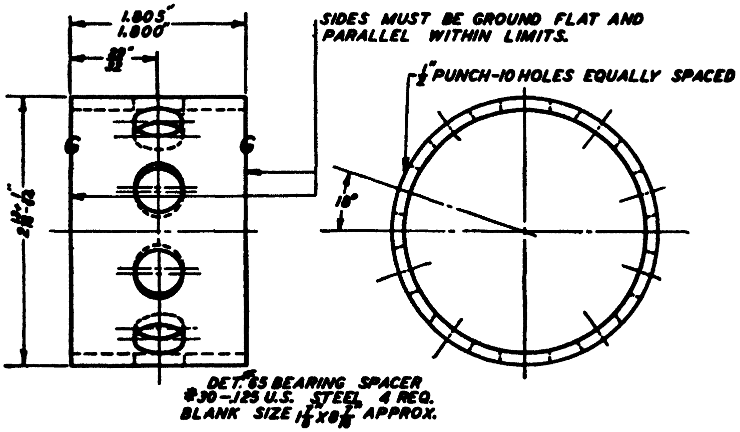

1.805″
1.800″
SIDES MUST BE GROUND FLAT AND PARALLEL WITHIN LIMITS.
PUNCH-10 HOLES EQUALLY SPACED
18°
DET. 65 BEARING SPACER
#30-.125 U.S. STEEL 4 REQ.
BLANK SIZE APPROX.

Fig. 52. Production Drawing for a Bearing Spacer

These pieces are welded to both rings, to make the complete fixture. This creates four sections, each accommodating five piece parts, making a total of 20 pieces ground on one side at each setup. After one surface has been ground, the piece parts are inverted in the fixture, are again mounted on the magnetic chuck; and the other end of each piece part is ground to the required dimension. Fixtures of similar design can be used for a wide variety of piece parts that are ground on one or both ends.

Fixtures for Use in Disk Grinding. There are a number of piece parts that are disk ground on the face so as to obtain a true surface for subsequent machining operations. Fig. 54 is a production drawing of a piece part which is a clutch fork bearing for a farm tractor. In section *B-B*, note the "G" on the face of this piece part which indicates that this section must be ground. This piece part is a gray iron casting and is somewhat irregular in shape. It would therefore be difficult to grind this without the use of a fixture; and, due to the quantity desired, it was necessary to design a fixture to do this job.

The upper drawing of Fig. 55 shows the top view of this grinding fixture, illustrating the piece parts in position in the fixture. The body of this grinding fixture is made of cast iron and is of angle-plate design, ribs being provided to add stiffness to the upright section of the fixture body. The lower drawing shows the front view of the fixture with two pieces clamped in it. The side view, Fig. 56, illustrates the design of the clamp (*9*). It will be noted that detail *11* is a hardened and ground clamp block that is serrated in order

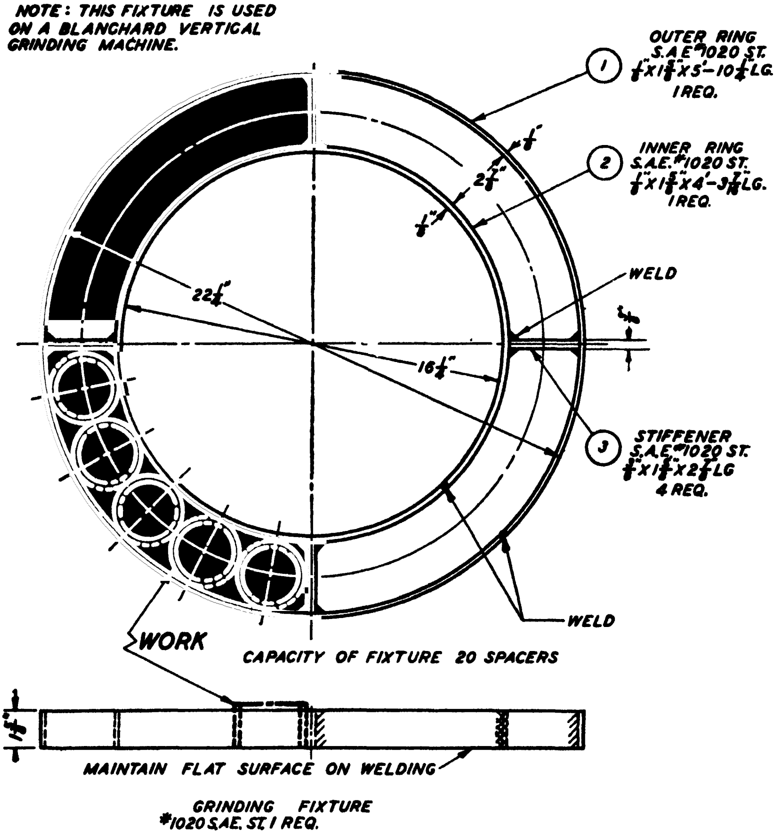

NOTE: THIS FIXTURE IS USED ON A BLANCHARD VERTICAL GRINDING MACHINE.
① OUTER RING S.A.E.#1020 ST. ¼"×1⅝"×5'-10¼" LG. 1 REQ.
② INNER RING S.A.E.#1020 ST. ¼"×1⅝"×4'-3⁷⁄₁₆" LG. 1 REQ.
③ STIFFENER S.A.E.#1020 ST. ¼"×1⅝"×2⅞" LG 4 REQ.
¼"
2¼"
¼"
22¼"
16¼"
WELD
WELD
¼"
WORK
CAPACITY OF FIXTURE 20 SPACERS
⅝"
MAINTAIN FLAT SURFACE ON WELDING
GRINDING FIXTURE #1020 S.A.E. ST. 1 REQ.

Fig. 53. Grinding Fixture for a Bearing Spacer

to prevent the piece parts from slipping in the fixture. The design of the clamp (*9*) is somewhat unusual to insure that these piece

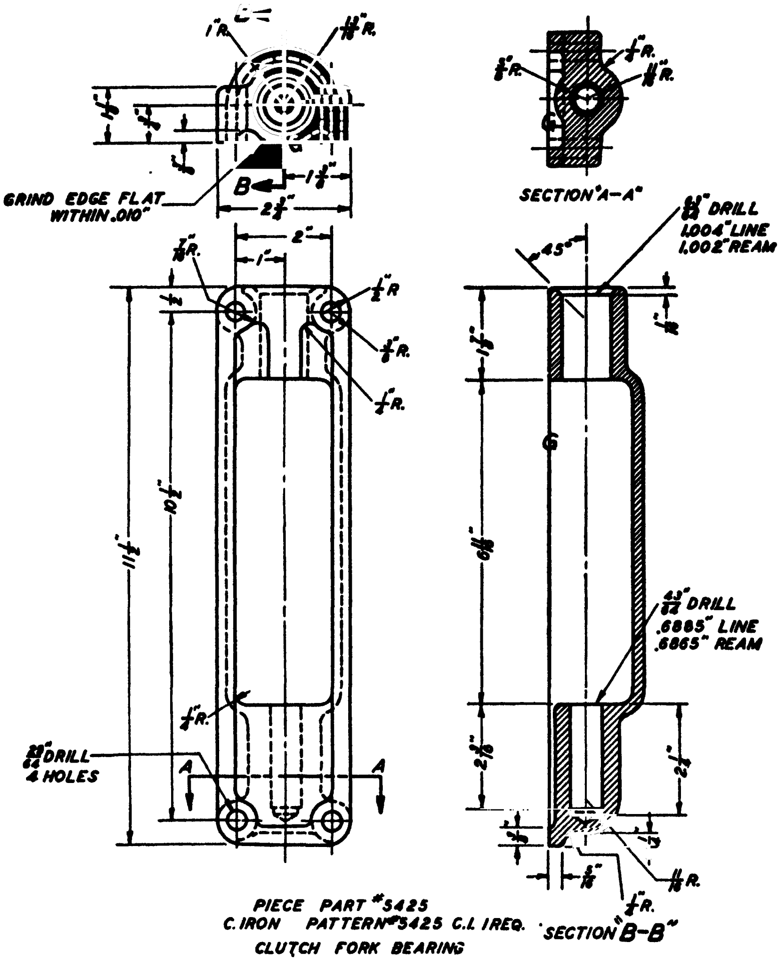


Fig. 54. Production Drawing for a Clutch Fork Bearing

parts will be held securely while the grinding operation is performed; therefore, serrated teeth are provided on the front end of the clamp. In order to provide a positive means for pulling this piece part back against the locating plates, the tail of the clamp is designed to have an angle of 30° and the section of the fixture body where the tail

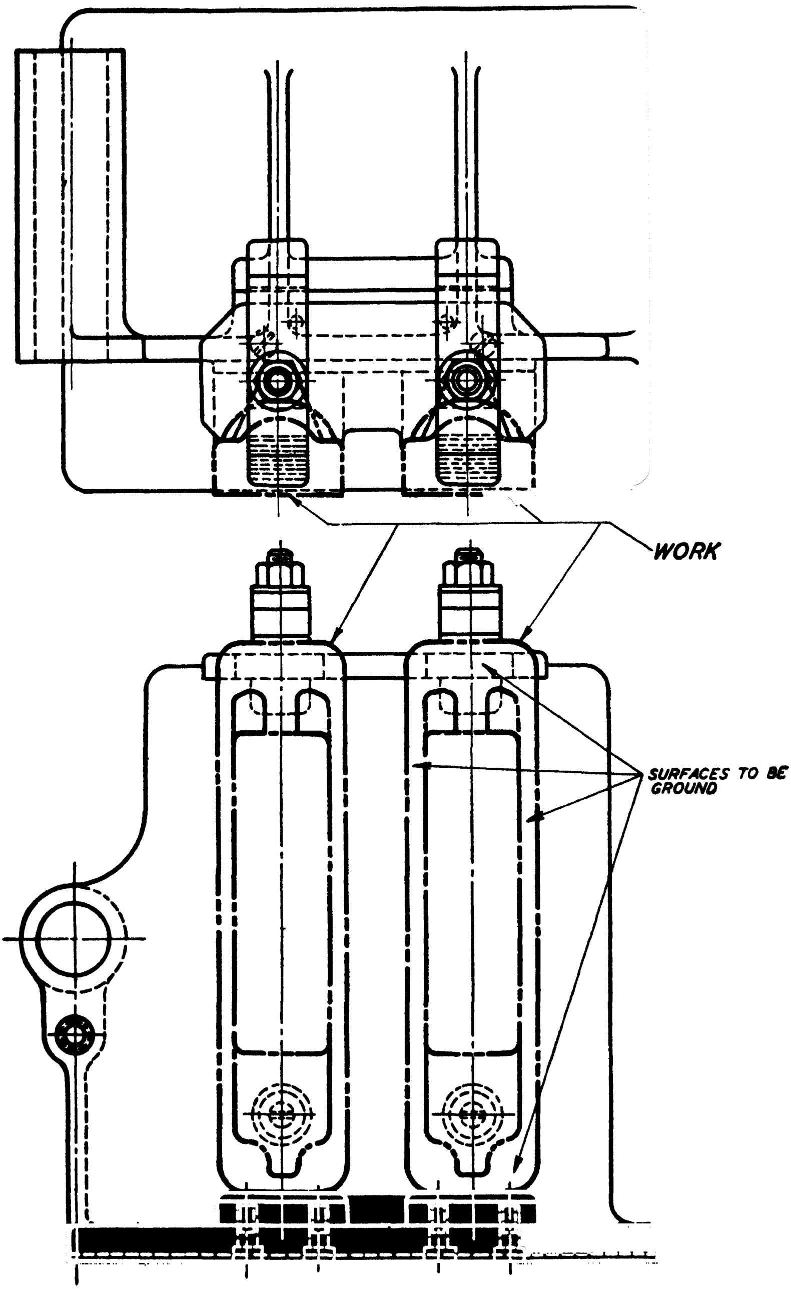
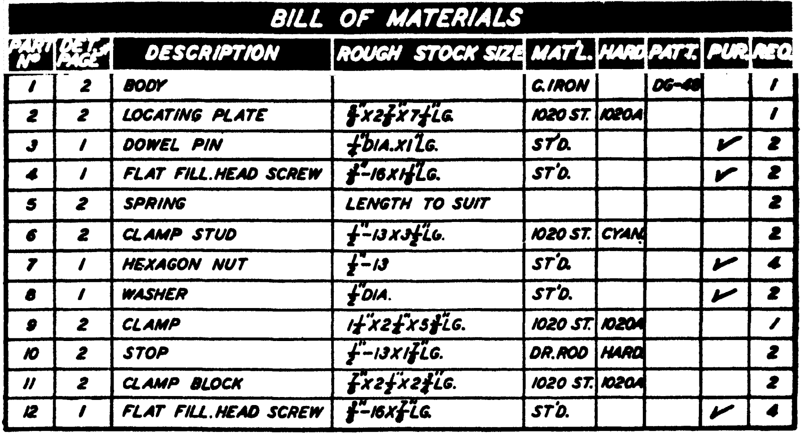


Fig. 55. High-Production Grinding Fixture for Clutch Fork Bearings



BILL OF MATERIALS

PART Nº	DET. PAGE	DESCRIPTION	ROUGH STOCK SIZE	MAT'L.	HARD.	PATT.	PUR.	REQ.
1	2	BODY		C. IRON		DG-48		1
2	2	LOCATING PLATE	$\frac{3}{8}$"X2$\frac{3}{8}$"X7$\frac{1}{4}$"LG.	1020 ST.	1020A			1
3	1	DOWEL PIN	$\frac{1}{4}$"DIA.X1"LG.	ST'D.			✓	2
4	1	FLAT FILL. HEAD SCREW	$\frac{3}{8}$"-16X1$\frac{1}{8}$"LG.	ST'D.			✓	2
5	2	SPRING	LENGTH TO SUIT					2
6	2	CLAMP STUD	$\frac{1}{2}$"-13X3$\frac{1}{2}$"LG.	1020 ST.	CYAN.			2
7	1	HEXAGON NUT	$\frac{1}{2}$"-13	ST'D.			✓	4
8	1	WASHER	$\frac{1}{2}$"DIA.	ST'D.			✓	2
9	2	CLAMP	1$\frac{1}{4}$"X2$\frac{1}{4}$"X5$\frac{3}{8}$"LG.	1020 ST.	1020A			1
10	2	STOP	$\frac{1}{2}$"-13X1$\frac{1}{2}$"LG.	DR. ROD	HARD.			2
11	2	CLAMP BLOCK	$\frac{7}{8}$"X2$\frac{1}{2}$"X2$\frac{3}{4}$"LG.	1020 ST.	1020A			2
12	1	FLAT FILL. HEAD SCREW	$\frac{3}{8}$"-16X$\frac{7}{8}$"LG.	ST'D.			✓	4

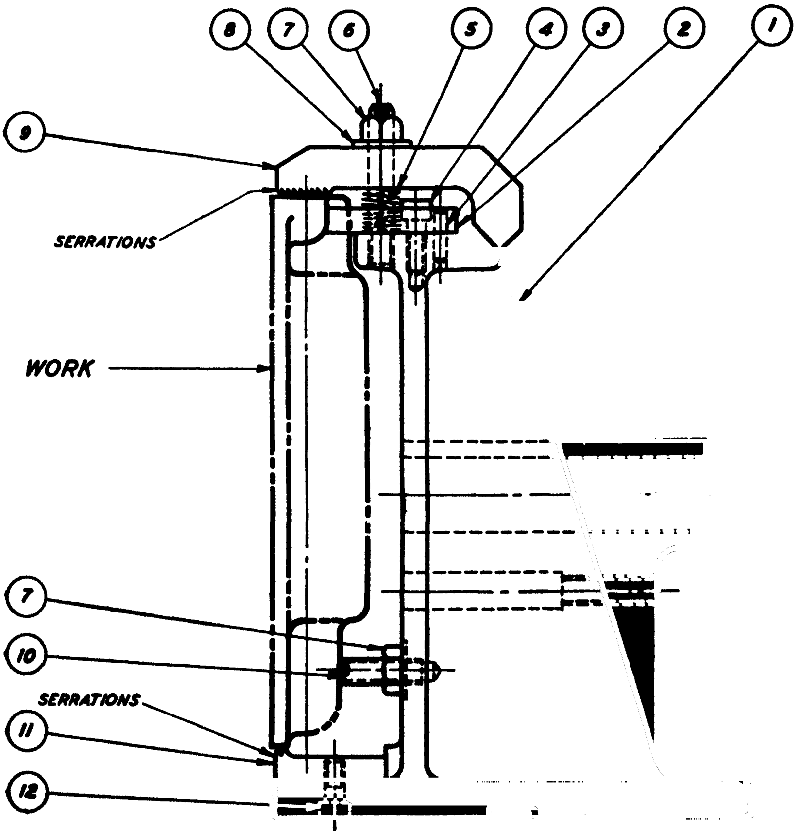


Fig. 56. Right Side Elevation and Bill of Materials for Grinding Fixture, Fig. 55

of the clamp rests is also machined to a 30° angle. The reason for this is that when the piece parts are loaded into the grinding fixture and the clamp tightened, the serrated teeth will hold the work, and the action of the angular sections (on the clamp tail and the fixture body) will have a tendency to pull the work back against the locating plate (detail *2*).

This piece part is ground in a disk grinding machine, with a steel face-plate to which is attached a grinding disk. The disk is mounted in a vertical position in the machine, and the fixture is clamped to the table and located by means of a keyway in the base of the grinding fixture. The piece parts mounted in the fixture then traverse back and forth across the face of the grinding disk to obtain a true surface.

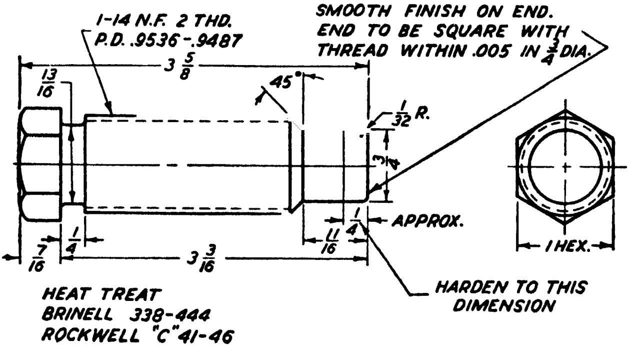


Fig. 57. Bevel Gear Deflection Set Screw

When it is necessary to design a grinding fixture for holding a number of piece parts similar to Fig. 57 on which the ends are hardened and where it is necessary to obtain a smooth finish after hardening, a fixture such as that shown in Figs. 58A and 58B is designed. Due to the design of the piece part, which is a set screw, and the large quantities in which these piece parts are produced, the fixture must be capable of holding a large number of parts. This grinding fixture, Fig. 58A, therefore was designed so that 22 parts can be loaded in the fixture at one time.

To prevent the parts from rotating by reason of the action of the vertical grinding wheel, it was necessary to design the inner portion in a spherical form with 22 V-sections.

In this fixture the work is clamped by means of the steel band (detail *2*) which is made out of spring steel. It forces the work against the vees of the inner ring, detail *3*. Clamping is accomplished by means of turning screw *9*.

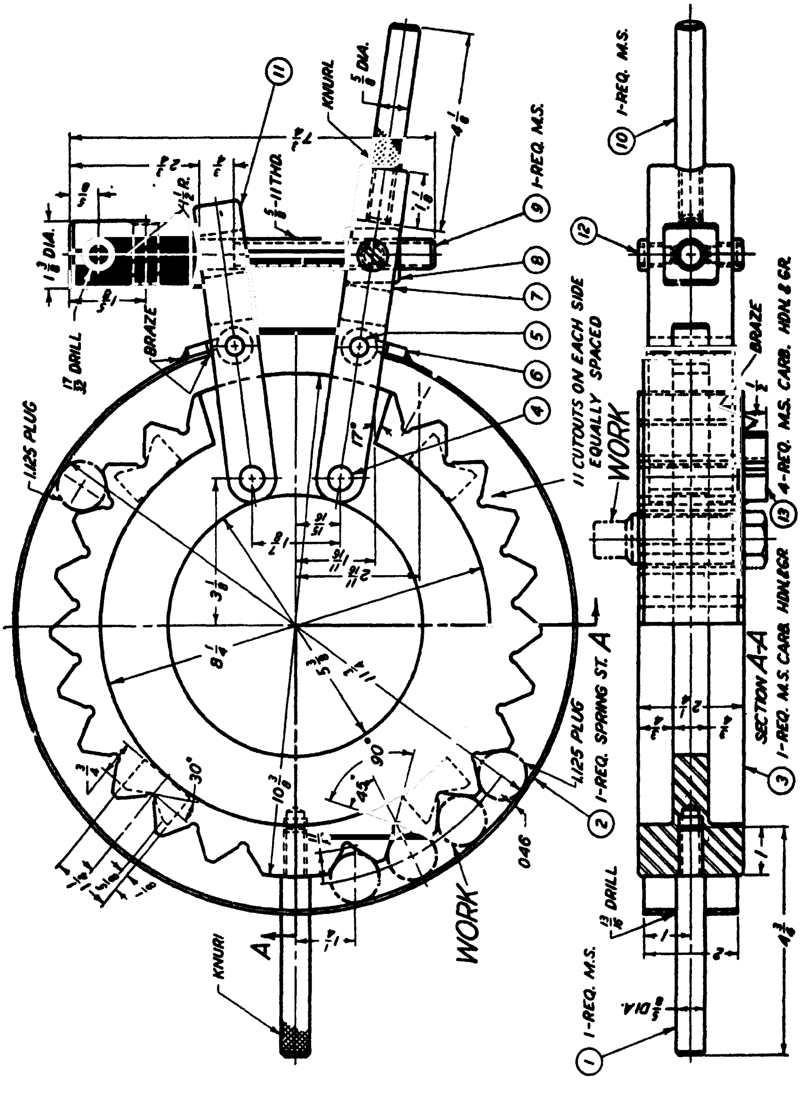
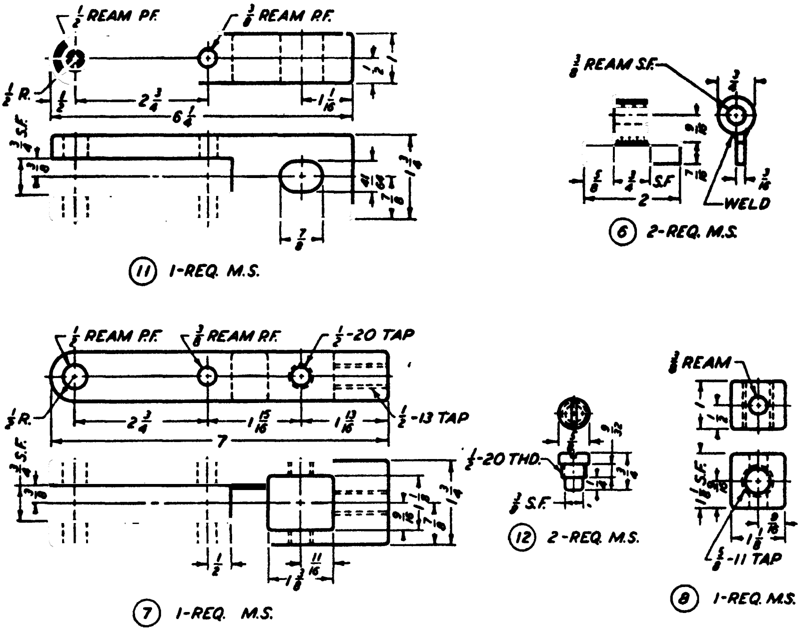


Fig. 58A. Fixture for Holding a Number of the Piece Parts Shown in Fig. 57

Detail *9* has a $1\,7/32''$ hole drilled in it at right angles to the axis so that a handle can be inserted to obtain the required leverage in clamping the pieces in the fixture. In action, this clamping ring is somewhat similar to the brake bands of an automobile and, when the pieces are loaded in the fixture and the screw (detail *9*) is tightened, it prevents the piece parts from rotating and tends to lock them in the fixture in a true vertical plane so that the specifications



No.	REQ.	NAME	MATERIAL	STOCK SIZE
13	4	REST LUG	M.S.	½ X ¾ X 1⅜
12	2	SCREW	M.S.	⅝ DIA. X 1¼
11	1	JAW	M.S.	1⅛ X 2 X 6½
10	1	HANDLE	M.S.	¾ DIA. X 4¼
9	1	SCREW	M.S.	1½ DIA. X 8
8	1	NUT	M.S.	1⅛ X 1¼ X 1¼
7	1	JAW	M.S.	1⅛ X 2 X 7¼
6	2	BAND HOLDER	M.S.	TO SUIT
5	2	PINS	DR. ROD	⅜ DIA. X 1¾
4	2	PINS	DR. ROD	½ DIA. X 1¾
3	1	RING	M.S.	10¾ DIA. X 2½
2	1	STEEL BAND	SPRING ST.	.046 X 2
1	1	HANDLE	M.S.	¾ DIA. X 5

Fig. 58B. Details and Bill of Materials for the Fixture Shown in Fig. 58A

on the piece-part drawing will be *followed; that is, the ends of the* piece part must be square with the thread within the limits specified, in this case .005″. The inner ring of the fixture has four rest lugs (*13*) brazed to it so that the fixture will be located on the magnetic chuck of the vertical grinding machine at the correct height. These lugs also permit the grit and abrasive materials to be cleaned out of the fixture, and it will be noted from the design of this fixture that the piece parts can be loaded and unloaded very rapidly. If the fixture were not designed in the manner shown here, it would be necessary to provide individual clamps for the piece parts, which would slow up production.

SPOTFACING FIXTURES

Spotfacing fixtures are designed for types of piece parts, particularly castings, which need machining only where a hole is drilled and it is desired to have a true surface for a shoulder of a shaft or head of a bolt. These are usually simple jobs and the spotfacing cutter is provided with a pilot that guides the cutter in the previously drilled hole.

On a part similar to a farm tractor clutch fork, a spotfacing fixture such as Fig. 59 is designed. On this piece part the drawing calls for spotfacing both ends of the hub section of this clutch fork and as this job is to be done in a drill press it is necessary that the fixture be designed so that both sides of this hub can be spotfaced in one setup. Therefore the fixture, as designed, consists of a base made out of steel with a hardened and ground plug pressed into it. This plug is designed to be made with a shoulder so that the piece part will rest on the shoulder while the spotfacing operation is being performed. A stop pin (detail *1*) is mounted in the base to prevent the piece part from turning. After one side has been spotfaced, the piece is turned 180° and the opposite side is spotfaced.

This particular fixture has been designed to accommodate three different sizes of piece parts. Note that there are three sizes of plugs provided (*3*, *4* and *5*) and a hole has been drilled and reamed in the base at the proper place to accommodate each. (See the top drawing of Fig. 59.) It is only necessary to press out the locating plug (detail *3*) from the base of the fixture and mount another plug of the desired size in the hole that has been provided for it in the fixture

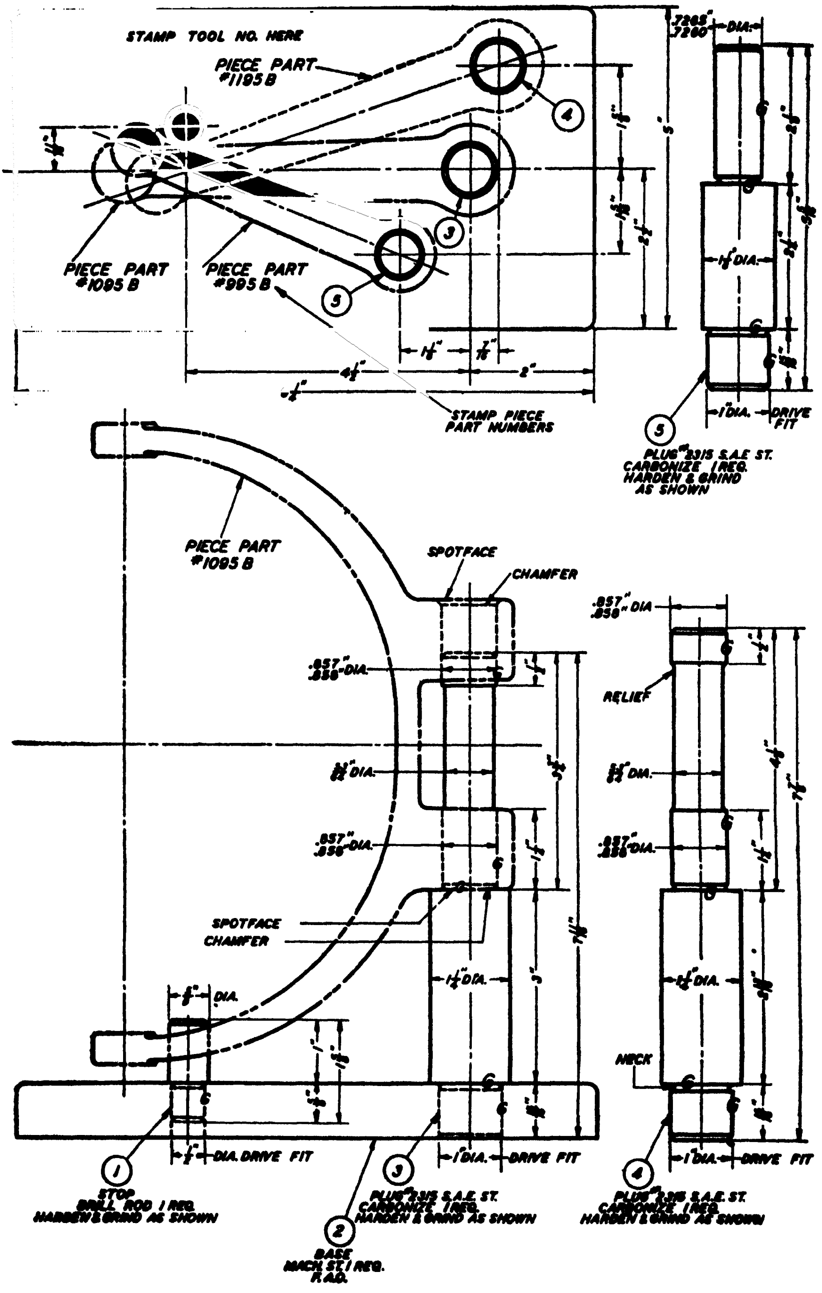


Fig. 59. Working Drawing of a Spotfacing Fixture for a Tractor Clutch Fork

base. Fixtures similar to the design illustrated here, consisting of a base plate and a plug are frequently designed for the spotfacing of both sides of cast-iron or steel levers and other miscellaneous parts. Usually fixtures for spotfacing pieces of irregular shape are designed similar to drill jigs except that no bushing plates or drill bushings are provided. On certain drill jig designs the spotfacing operation can be performed by having large liner bushings that will guide the spotfacing tool.

TAPPING FIXTURES

Usually the tapping operation on piece parts can be performed immediately after the drilling operation and using the same jig; but on certain classes of work it is often necessary to do the tapping in a tapping machine or in another drill press by means of a tapping attachment. When a condition of this kind is met, tapping fixtures are sometimes necessary due to the design of the piece part. For many second operations on screw machine parts, simple tapping fixtures are necessary.

Fig. 60 is a design of a simple tapping fixture for tapping a hole in a piece part that is produced in a screw machine. This cross hole, due to its small size, is drilled in a sensitive bench-type drill press. This being a single-spindle machine it would be expensive to drill and tap a piece part of this kind in one operation; therefore a tapping machine is employed and a fixture similar to the one shown in Fig. 60 is designed. This consists of a body made out of a piece of hexagon-shaped cold-rolled steel, with a hole drilled and tapped in the bottom for attaching it to the table of the tapping machine. A vee is milled in the upper portion of the fixture body and two top plates are mounted by means of screws. The work is then slid into the vee section of the fixture for the tapping operation. Chip clearance holes are drilled in the body so that the chips will fall through the hole and prevent interference with the work.

Tapping fixtures are somewhat similar to drill jigs, in general, but they do not have bushing plates or guide bushings, as it is not necessary to guide the tap because the tap will usually follow the drilled hole. Therefore, the tool designer, when confronted with the problem of designing a tapping fixture, should employ the same design methods used for a drill jig, except as previously noted.

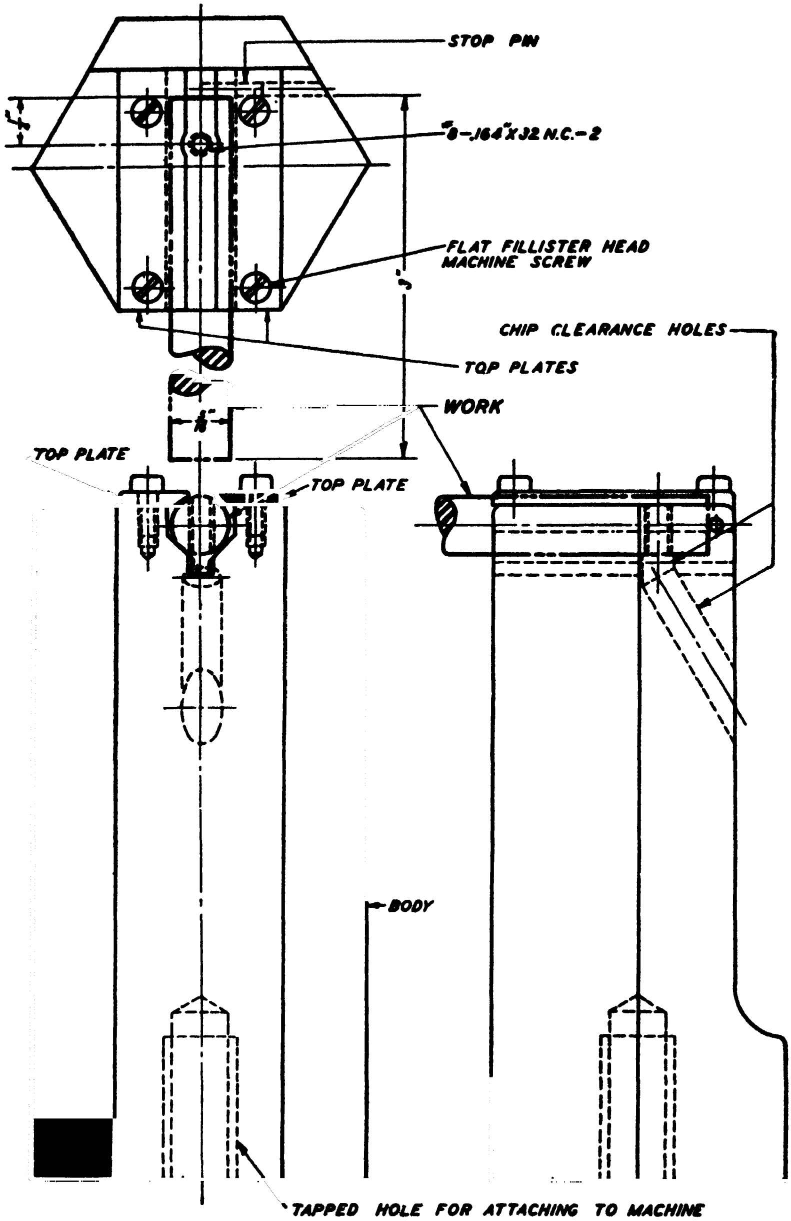


Fig. 60. High-Production Tapping Fixture for Tapping ⅛" Diameter Round Rod

PLANING FIXTURES

Most machining operations that are performed in a planer are done without the use of fixtures because of the fact that it is usually large work and the piece part is set up by means of angle plates, blocks, straps and clamps; and after one side has been planed, the piece part can usually be located directly on the table and fastened to it by means of various types of clamps or straps. However, on certain jobs that must be produced in fairly large quantities, and when no other type of machine is available for the purpose, planing fixtures are designed.

For a piece part such as a round shaft that is used for an axle, and where it is desired to have a flat at a certain point on this axle, the job is sometimes done in a planer. Therefore a fixture similar to Fig. 61 is designed. This planing fixture consists of a steel base (*1*) with six **V**-grooves machined in it so as to accommodate six shafts 4¼″ in diameter. Six long dowel pins ¾″ in diameter by 3¼″ long (*4*) are inserted in the slots at the bottom of the **V**-grooves so as to locate the shafts in the correct position in the fixture. Six studs are designed to be mounted in between the **V**-grooves so that forged steel **U**-clamps can be employed for clamping the piece parts in the fixture. These are shown by detail *9*. This design of clamp is employed because it is easy to slip them off the stud for loading and unloading the piece part. Springs are not put under the clamp as they would be unnecessary with a clamp designed in this manner.

On the lower portion of Fig. 61 is a series of steps that are given in decimal dimensions as follows: *1.750″ plus or minus .002″*; *.500″ plus or minus .002″*. These steps have been provided for setting the planer tool in machining the piece parts.

Note that the base of this fixture is provided with keys (*3*) similar to those used in milling machines. These keys are for locating the fixture on the planer table in the correct position. **U**-slots have been provided on either end of the base of the fixture so that it can be firmly clamped to the planer table. Inasmuch as planer fixtures are somewhat similar to milling fixtures, and typical examples of milling-fixture design were illustrated and described at the beginning of this section of the book, no other types of these fixtures will be illustrated or described.

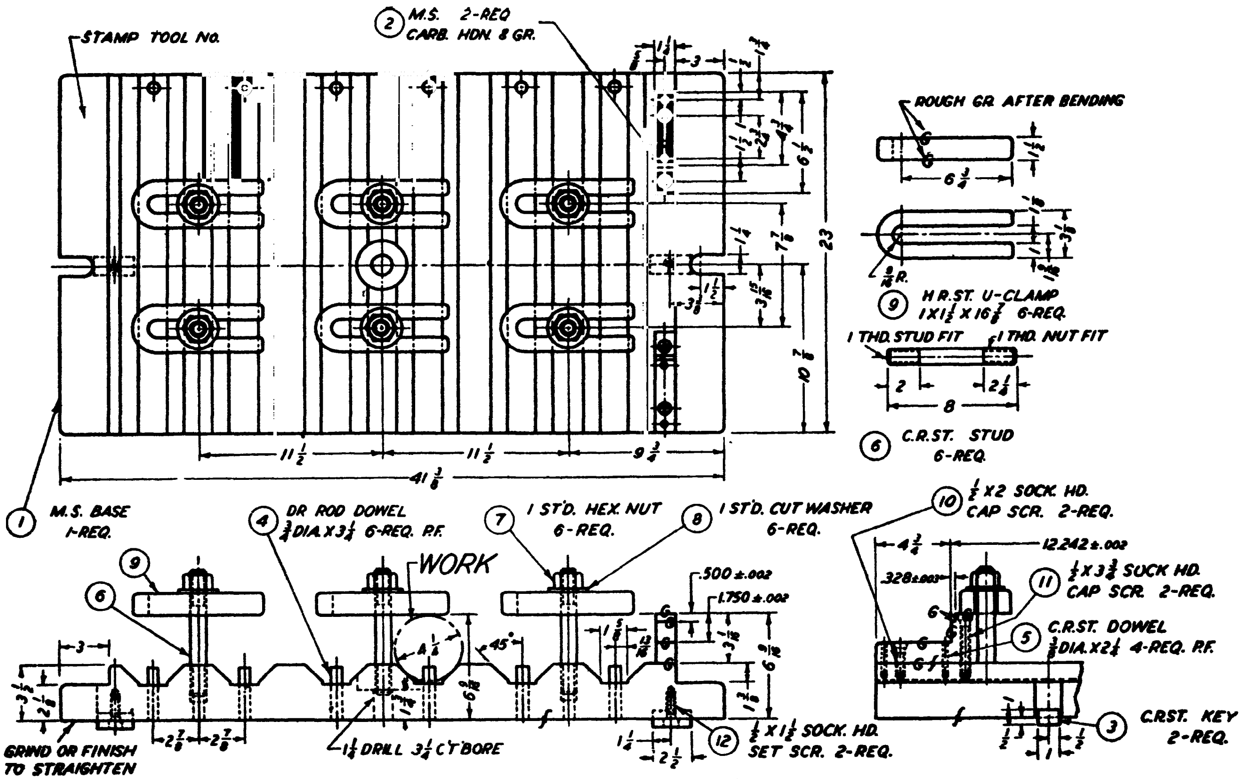

STAMP TOOL NO.
② M.S. 2-REQ CARB. HDN. 8 GR.
ROUGH GR. AFTER BENDING
⑨ H.R.ST. U-CLAMP 1X1½X16⅞ 6-REQ.
1 THD. STUD FIT
1 THD. NUT FIT
⑥ C.R.ST. STUD 6-REQ.
① M.S. BASE 1-REQ.
④ DR. ROD DOWEL ¾DIA.X3¼ 6-REQ. P.F.
⑦ 1 STD. HEX. NUT 6-REQ.
⑧ 1 STD. CUT WASHER 6-REQ.
⑩ ½X2 SOCK. HD. CAP SCR. 2-REQ.
⑪ ½X3¾ SOCK. HD. CAP SCR. 2-REQ.
⑤ C.R.ST. DOWEL ⅜DIA.X2¼ 4-REQ. P.F.
③ C.R.ST. KEY 2-REQ.
⑫ ½X1½ SOCK. HD. SET SCR. 2-REQ.
WORK
1¼ DRILL 3¼ C'TBORE
GRIND OR FINISH TO STRAIGHTEN
.500±.002
1.750±.002
12.242±.002
.328±.002
45°
41⅛
23
11½
11½
9¾
10⅞
7⅞
6½
6¾
8
2
2¼
2⅞
2⅞
3
4½

Fig. 61. Planing Fixture for Track Roller Axle

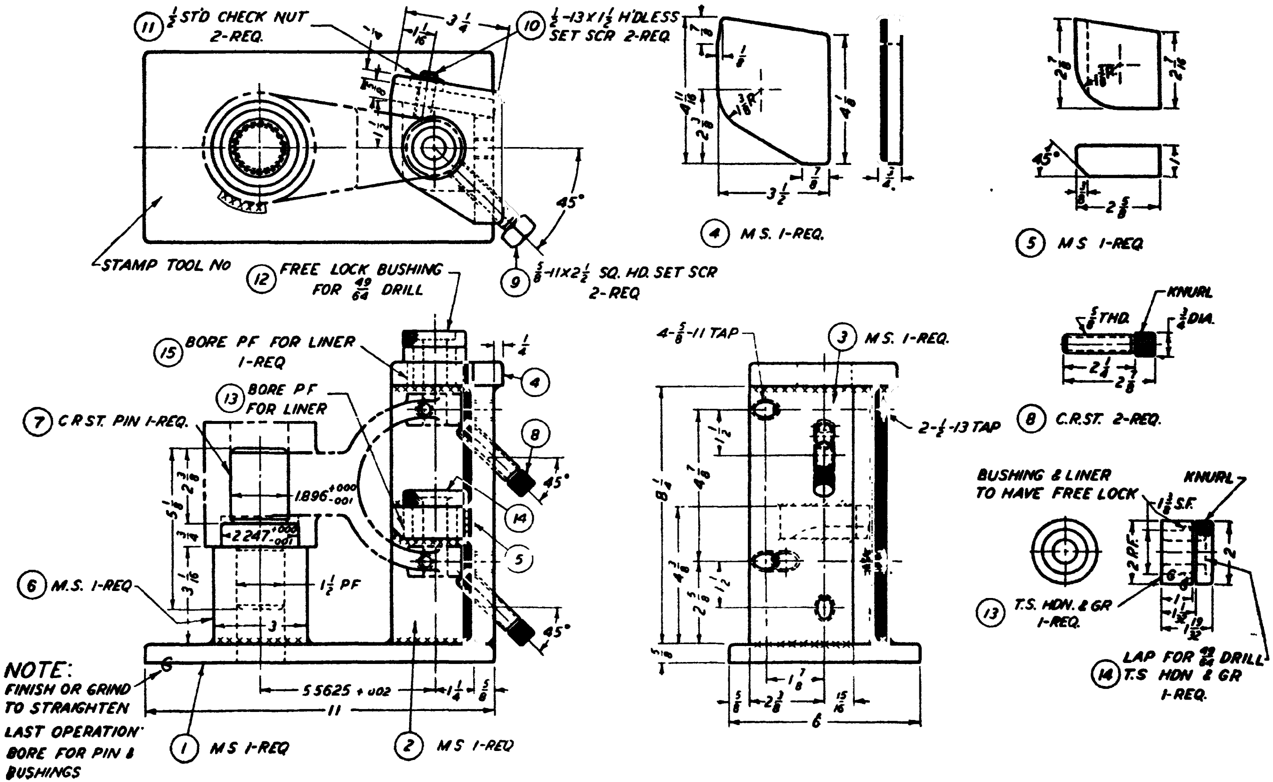


Fig. 62. Welded Steel Drill Jig

WELDED JIGS AND FIXTURES

The use of welded jigs and fixtures has been constantly increasing. In some manufacturing plants practically all types of jigs and fixtures are designed to be made of welded steel construction. In many cases the jig or fixture would be a better job if it were designed to be made from a casting. Good judgment must be used by the tool designer in specifying the type of construction. In many instances welded steel construction is stronger, better, and cheaper than a fixture designed to be made from a casting. On certain types of fixtures a casting is the correct design to be used. However, the question of whether to choose welded steel or castings in designing jigs and fixtures is the subject of many arguments. The personal experience of the tool designer as to the results obtained from the use of these types of construction is usually the basis for his choice of the type of materials and construction to be used in the jigs and fixtures he designs.

There are certain symbols that are frequently used in the design of welded jigs and fixtures. In the appendix will be found a chart showing the various symbols used in arc welding. By using these symbols, considerable time is saved in the fabrication of jigs and fixtures made of welded steel construction.

Fig. 62 shows the design of a welded steel drill jig. Welding symbols are indicated at the points where the various details of this drill jig are welded to the machine-steel base. The design of this jig is such that welded steel construction is the least expensive. This design is being shown here to give the tool designer an idea of the correct use of symbols for welded steel construction.

QUIZ QUESTIONS

1. When the word "fixture" is used in metalworking plants, what type of device is usually meant?

2 What is the primary purpose of a fixture?

3 In designing milling fixtures, what are some of the essential points to be considered?

4 Before designing a milling fixture, why is it essential to get all available information concerning the dimensions of the milling machine table on which the fixture is to be used?

5 If the fixture design shown in Fig 4 were to be used for producing piece parts in large quantities, what changes would be made in its construction?

6 What are some of the special features of the fixture shown in Fig 5?

7 In designing a straddle-milling fixture, what precautions must be taken in regard to the cutter and fixture?

8 What is the distinctive feature of the clamping device used in connection with the fixture shown in Figs 19 and 20?

9 What types of jobs use fixtures similar to Fig 22?

10 When designing milling fixtures, what consideration governs the number of piece parts the fixture will be designed to hold?

11 What are some of the special features on the milling fixture shown in Fig 27?

12 What is the special value or characteristic of broaching operations?

13 What points do broaching fixtures have in common with other types of drill jigs and milling fixtures?

14 In making serrations on a piece part what method other than cutting them with milling cutters is now in general use?

15 In designing boring fixtures, how does the length of the guide bushing compare with the diameter of the boring bar used in the fixture?

16 In the boring fixture illustrated in Fig 49, how are the pilot bushings placed and what is their function?

17 In the fixture shown in Figs 55 and 56, what are some of the special features in the clamping methods used for holding the piece part?

18 What are the special features of the fixture shown in Figs 58A and 58B?

19 In designing tapping fixtures, what distinctive difference is there in comparison to the design of a drill jig fixture?

20 Discuss the use of welded jigs and fixtures

TILTING WELDING FIXTURES MADE OF WELDED STEEL PLATES, USED FOR MAKING STEEL TRUCK BODIES

Courtesy of The Anthony Co , Streator, Ill

DIES

In modern metal-manufacturing plants the use of metal stampings has been constantly increasing due to the fact that stampings produced from flat sheet metal have proved more economical than castings on a great many parts. Formerly, castings were used extensively for a number of parts because the size of the power punch press was a limiting factor. At the present time, the size of power punch presses is limited only by the demands made by the metal-manufacturing plants. In the automotive industry the entire turret top of an automobile is made from a single piece of sheet metal.

Stampings have another advantage over castings made of various materials: when a stamping is produced by means of dies and a punch press, the piece is usually completely finished. Subsequent operations are required on certain types of stampings; for example, the welding of brackets or sections of metal that would be heavier in cross section than the sheet metal the stamping was made from.

In designing dies, a great many of the same points that have been emphasized in previous chapters must be given careful consideration by the tool designer. They are as follows: the type of die to be designed, the number of parts to be produced. and the capacity of the power punch presses that are available in the plant. The tool designer should always make a careful study of the part to be produced, then determine the type of die that he will design. The die must always be small enough in area to fit the die space in the punch press on which it is to be used.

The designer should also see that the height of the die is kept within the limits of the shut height of the punch press. A die consists of two parts: the upper, or punch section; the lower, or die section. When the two parts are put together, this equals the overall height of the die. The shut height in a punch press is the distance from the bolster plate to the lower part of the ram when the punch press is in the closed position, or at the bottom of the press stroke. The die should always be designed so that the stroke of the press will permit of enough clearance to load and unload the piece part from the die.

Punch presses are made in a variety of types and in almost unlimited sizes, from the small bench press, to the foot-kick press which is operated by means of a counterweight and foot lever, to the largest type of motor-driven and hydraulically operated punch presses.

The tool designer should try to keep the design of a die as simple and economical as possible. The piece part to be produced should be laid out on the tracing paper with a red pencil, and the die should be developed around this piece-part layout, from the center to the outside. The reason for this is that if the layout of the die is started from the outside, by the time the tool designer gets into the center of the piece part he possibly will find that there are interferences that will make the design useless. As an example, in designing a blanking die it might be found that, working from the outside diameter of the blank, not enough stock had been allowed in the die section to make a correct tool. Thus on all types of dies it is advisable to work from the center of the piece part outward, as in this manner sufficient stock can be added to the die where needed.

When laying out forming dies, the tool designer should have the bends at right angles to the grain of the metal, particularly in making right-angle bends. This rule can be ignored in the case of some of the softer grades of steel, brass, copper and other metals. A sufficient radius must be allowed in the die to take care of right-angle bends. This radius should be equal to the stock thickness, or larger if possible.

The layout of the die should take into consideration the most economical use of the material from which the piece part is to be made. It is considered good practice to make a paper template of the required piece part from a piece of heavy drawing paper. A piece of tracing paper is then used to represent the material, and the template is moved about on it until it is determined just what position will be most economical of material. This eliminates considerable stock waste. On only a few parts this stock waste might not mean much, but on a large number of pieces stock waste would be considerable and expensive.

After the tool designer has carefully studied the piece-part drawing and has decided what type of die he is going to design, he

Punch Press Data

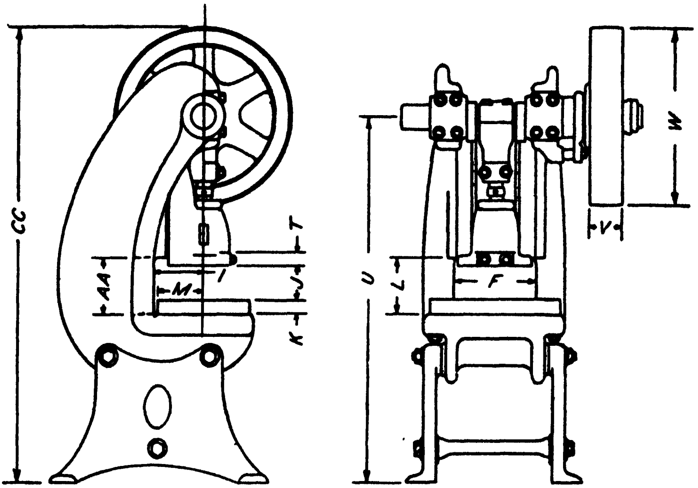
Name of press	Toledo	Consolidated	Consolidated	Consolidated	Verson	Bliss	Niagara	Niagara	Bliss
Size	5	6	5	3	3	54	156	510	58
Mach. No.	1964	976	899	2810	2836	2820	2808	2843	2825
Stroke of ram	2½	3½	3	2	2	1½	10	12	......
Adjustment of ram	5½	5	4	2	2	None	5	4	......
Maximum die space	8½	9¼	8	6⅜	6¼	9½	10	14½	......
Bolster width F-B	18¼	22	17	12	12	12	19½	32	38
Bolster length R-L	27½	34	29½	20	21¾	16	19	28½	33
Bolster thickness	2	2¼	2	1¼	1½	1½	2⅜	3	4
Opening in bolster F-B and R-L	6 D.	9¼D.	5¾D.	5 D.	6 D.	4	6½	6½x7	4
Opening in machine bed F-B and R-L	12x16	17 D.	14 D.	8½ D.	8½ D.	7	*	16x16	25
Ram width F-B	......	......	......	......	......	......	7¼	19	......
Ram length R-L	......	......	......	......	......	......	9¼	23	......
Diameter of punch shank	2½	2½	2½	1⁹⁄₁₆	1⁹⁄₁₆	1⁹⁄₁₆	2	3	......
Height of punch shank	2½	3	2½	2⅜	2⅜	2⅜	2½	3	......
Max. diameter of knockout pin	......	1	¾	⅝	⅝	No	⅝	1	......
Max. ht.—K.O. pin above P. shank	......	2	2½	1¼	1¼	No	3	5	......
Throat distance from C.L.▲ of ram	......	11	8¼	6	6¾	6	......	.....	......
C.L.▲ of ram back to C.L.▲ of guide pin†	......	6	4½	3	3	‡	‡	‡	......
C.L.▲ of ram R and L to C.L.▲ of guide pin†	......	7	5½	4½	4½	‡	‡	‡	......
Length of air cushion pins§	......	......	......	......	......	......	......	7	......
Opening in sub-bolster	......	......	......	......	.....	.....	......	12x12	......
Thickness of sub-bolster	......	......	......	......	......	......	......	4	......
Tonnage of press	87½	56	36	22	26½	36	43	188	215

*Must use bolster.
†Applies only when guide pins protrude above upper die shoe.
‡Must be below closed die.
§Minimum below shoe when die is open.
▲Center line.

Fig. 1

should check up on the capacities of the punch presses available in the plant. In many of the metal-manufacturing plants, a data sheet, Fig. 1, is provided. In this sheet all the necessary dimensions of the available punch presses are given. The tool designer, by looking at the data sheet, can usually determine what press the die should be designed for. The open-back inclinable punch press is one frequently used in the large majority of plants. This type of press is suitable for many punch-press operations that are performed in the average metal-manufacturing plant. The data sheet, Fig. 2, gives the tool designer all the necessary information. By referring to the data sheet in Fig. 1, the various dimensions given can be located by again referring to Fig. 2.

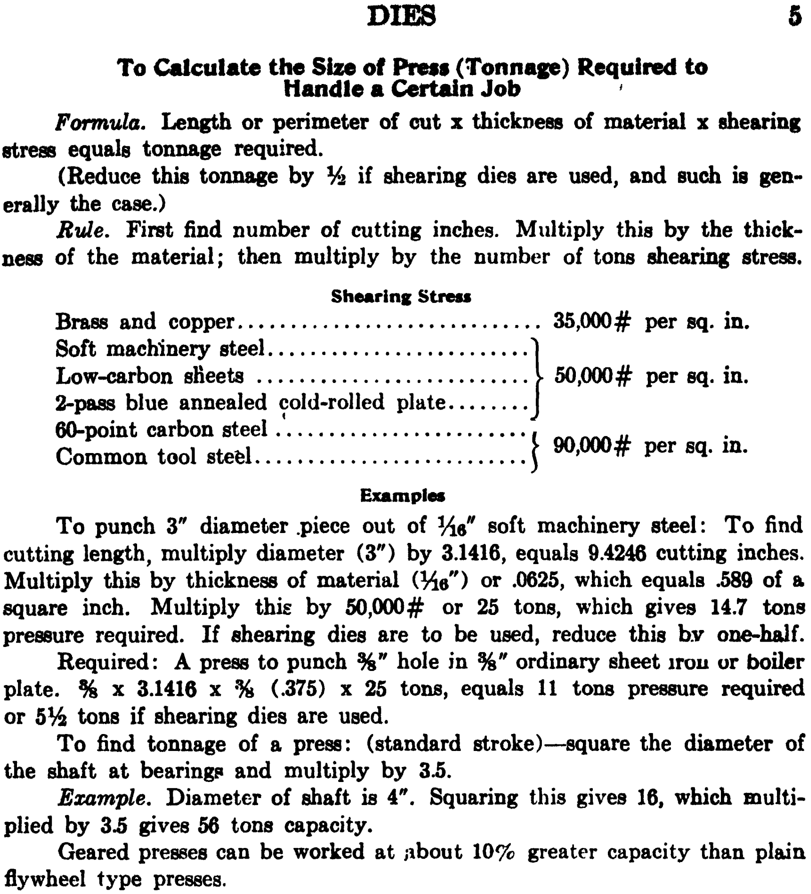
The types of dies most frequently used in the average plant are piercing dies, blanking dies, cutoff dies, and parting dies. The size of the part and thickness of material are the determining factors in the size of the punch press to be used. The pressure required to blank or pierce certain thicknesses of material is determined by formulae that have been developed through many years of experience, and the tool designer uses these formulae in determin-



DD BED INCLINATION FROM HORIZONTAL DOWN
EE TONS PRESSURE REQUIRED
FF FLYWHEEL SPEED R.P.M.
GG SHAFT DIAMETER AT JOURNAL
HH SHAFT DIAMETER AT CRANK
JJ HORSEPOWER REQUIRED
KK STROKE
LL ADJUSTMENT OF RAM DOWNWARD
MM FLOOR SPACE OVERALL F TO B x R TO L
NN WEIGHT

PRESS	AA	CC	DD	EE	FF	GG	HH	JJ	KK	LL	MM	NN	F	I	J	K	L	M	T	U	V	W
C11	10	71	40	10	130	2	2¼	1	2	3	28×36	1325	11½	5	6½	2	11	3½	3	60	3	20
C12	10	75	40	20	120	2½	2¾	2	2	3	35×39	2300	13	6	7	2	11½	4½	3	62	4	25
C13	10½	80	40	30	110	3	3½	3	2	3	41×44	3000	14½	7	7½	2½	12½	5½	3	65	5	30
C14	11	86	35	40	100	3½	4¼	5	2½	3	49×50	4900	17	9	7½	3	13½	7½	3	68	6	35
C15	11½	92	30	55	90	4	5	5	3	3	57×57	8000	20	12	8	3½	15	10½	3	72	7	40
C16	11½	101	30	75	80	4¾	5¾	7½	3½	3	70×66	11000	20	12	9	4	17	10½	3	78	8	45
C17	12	108	30	110	70	5½	6½	10	4	3	74×70	16000	24	16	10½	4	19	14½	3	84	9	50
C21	11	72	40	10	150	2	2¼	¾	2	2	28×32	750	7	4	7¼	1¼	11	4	2½	62	3	20
C21 A	11	72	40	10	150	2	2¼	¾	2	2	28×32	1000	8	6	7	1½	11	6	2½	62	3	20
C22	11	76½	40	20	150	2½	2¾	1	2	2½	35×34	1300	8	4½	7	1½	11	4½	2½	64	4	25
C22 A	11	76½	40	20	150	2½	2¾	1	2	2½	35×34	1600	9½	6½	7	1½	11	6½	2½	64	4	25
C23	12	81	40	30	125	3	3½	2	2	2½	41×40	2400	9½	6½	7¾	1¾	12	6½	2½	66	5	30
C23 A	12	81	40	30	125	3	3½	2	2	2½	41×40	2900	13	9	7¼	2	12	9	2½	66	5	30
C24	13	87½	35	40	100	3½	4¼	3	2½	3	49×46	4300	13½	9½	7½	2½	13	9½	3	70	6	35
C25	14	87½	30	55	100	4	5	5	3	3	57×52	5300	12½	9	8	2½	14	9	3	70	7	40
C25 A	14	93½	30	55	100	4	5	5	3	3	57×52	10000	15	11	7¾	2¾	14	11	3	73½	7	40

Fig. 2. Open-Back Inclinable Punch Press



DIES 5

To Calculate the Size of Press (Tonnage) Required to Handle a Certain Job

Formula. Length or perimeter of cut x thickness of material x shearing stress equals tonnage required.

(Reduce this tonnage by ½ if shearing dies are used, and such is generally the case.)

Rule. First find number of cutting inches. Multiply this by the thickness of the material; then multiply by the number of tons shearing stress.

Shearing Stress

Brass and copper	35,000# per sq. in.
Soft machinery steel Low-carbon sheets 2-pass blue annealed cold-rolled plate	50,000# per sq. in.
60-point carbon steel Common tool steel	90,000# per sq. in.

Examples

To punch 3″ diameter piece out of $\frac{1}{16}$″ soft machinery steel: To find cutting length, multiply diameter (3″) by 3.1416, equals 9.4246 cutting inches. Multiply this by thickness of material ($\frac{1}{16}$″) or .0625, which equals .589 of a square inch. Multiply this by 50,000# or 25 tons, which gives 14.7 tons pressure required. If shearing dies are to be used, reduce this by one-half.

Required: A press to punch ⅜″ hole in ⅜″ ordinary sheet iron or boiler plate. ⅜ x 3.1416 x ⅜ (.375) x 25 tons, equals 11 tons pressure required or 5½ tons if shearing dies are used.

To find tonnage of a press: (standard stroke)—square the diameter of the shaft at bearings and multiply by 3.5.

Example. Diameter of shaft is 4″. Squaring this gives 16, which multiplied by 3.5 gives 56 tons capacity.

Geared presses can be worked at about 10% greater capacity than plain flywheel type presses.

Fig. 3

ing the size of press required for the particular die he is to design.

Fig. 3 is a data sheet showing the necessary formulae. By following the rules contained in this data sheet, the tool designer is able to determine the press capacities needed.

To design dies for parts that have to be notched, pierced and formed, it is sometimes necessary for the tool designer to make a drawing showing the blank development of the piece part. This is of considerable assistance in designing the die and also helps the die maker in the plant tool room. Fig. 4 is a part drawing showing the developed size of the blank for a tractor drawbar plate brace.

In designing dies, they should be laid out showing the front view of the upper and lower portions of the die in the closed position. This tells the tool designer that the dimensions shown are not too small to take the piece part. The other view that should be drawn will show upper and lower parts of the die laid back with the working faces visible. This means that the die section and the

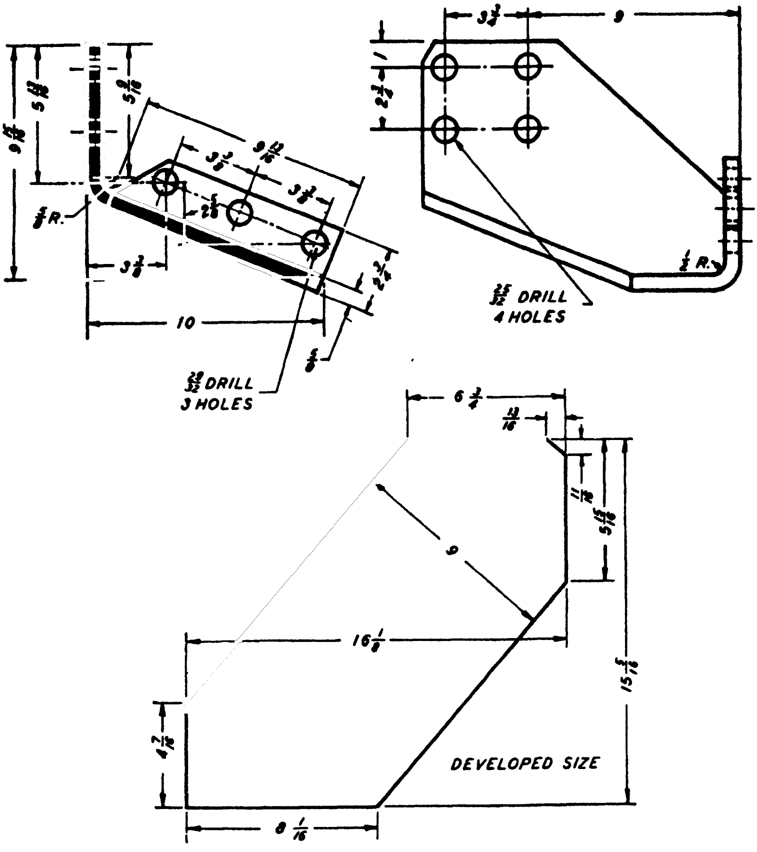


Fig. 4. Drawbar Plate Brace

punch section will be shown and the tool maker will have a clearly defined picture of the construction of the die. The tool designer should always specify, and show with a red outline, the work to be performed by the die and the kind of material to be used in the construction of the die. The designer should always be sure that the press for which the die is designed has enough power to do the job. The assembly tool drawing of the die should, wherever it is possible to do so, show the detailed dimensions of the various sections that compose the die; however, in the event that this would make it impossible to provide a good working drawing, additional sheets should be drawn showing these details.

In some of the larger plants, standards are used for the punch and die sections of dies, particularly on certain types of presses.

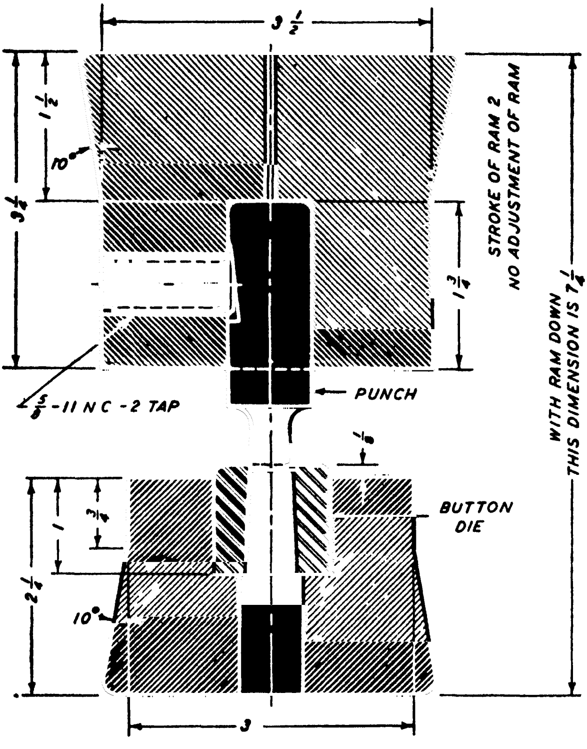


Fig. 5. Standard Punch and Die Block

Fig. 5 is a standard punch and die block used for rail dies. These standard sheets save considerable time for the tool designer, as all necessary dimensions are given and the only thing he has to calculate in laying out a die of this type is the length and, of course, the location of the punches and the die buttons.

In the majority of metalworking plants, standard punch and die sets are purchased. These are commercially available in a large variety of standard lengths and widths. In addition, special die sets can be purchased very cheaply from the manufacturers. These large special sets are usually made from steel plate and are burned out, by means of a torch, to the required shape and size. If leader pins and guide bushings are required, these can also be purchased commercially and the die set manufacturer will attach these to the die set. Therefore, the former practice of making various designs of die sets in the individual metalworking plant has been largely discontinued.

There are many types and designs of dies, and it would be impossible to cover all of these in a book of this kind, therefore only the most generally used types will be described and discussed. There has been considerable improvement in the quality and types of materials available for stampings. This is also true in regard to materials that the dies themselves are made from. The various technological developments of metal-cutting materials has made it possible to produce stampings that were considered impossible only a few years ago. The selection and specification of the right materials by the tool designer are very important, and the tool drawing of the die should contain these specifications as well as the proper heat treatment.

The tool designer should always keep in mind that the stock from which the stamping is to be made must be stripped from the punch or the die, therefore proper stripping facilities must be provided in the die. The stripping can be done by various means: it can be a solid stripper, a stripper plate mounted to the punch holder of the die by means of stripper bolts and having springs to push the blank off the punch; or a knockout bar can be provided in the punch holder so as to strip the piece from the punch section of the die. Rubber is also used for strippers.

Piercing Dies. The simplest type of die is the perforating or piercing die, Fig. 6. In this illustration a round hole is perforated or pierced in a piece of strip steel. The punch is provided with a clearance angle so that the stock material will not bind on the punch. The die section is also provided with clearance so that the slug that is obtained from the piece of strip steel will not stick in the die. Clearance for perforating dies must be provided between the punch and the die section; this clearance usually equals 10 per cent of the thickness of the stock. Therefore if it is desired to punch a 1″

round hole in a piece of sheet steel whose thickness is .100", the diameter of the hole in the die would be 1.010", the diameter of the punch would be 1.000". This clearance rule is general and will vary with the thickness of the stock the die is designed to perforate. On very thin materials this 10 per cent of the thickness of the material to be punched can be varied in accordance with the needs of the job to be done. In Fig. 6, at *A*, is an illustration of this clearance between the punch and die. These clearances are exaggerated to illustrate the point discussed. At *B* is a sectional view showing the punch and die with the stock ready to be perforated. *C* shows the action of the punch and die in piercing a round hole in a piece of strip steel.

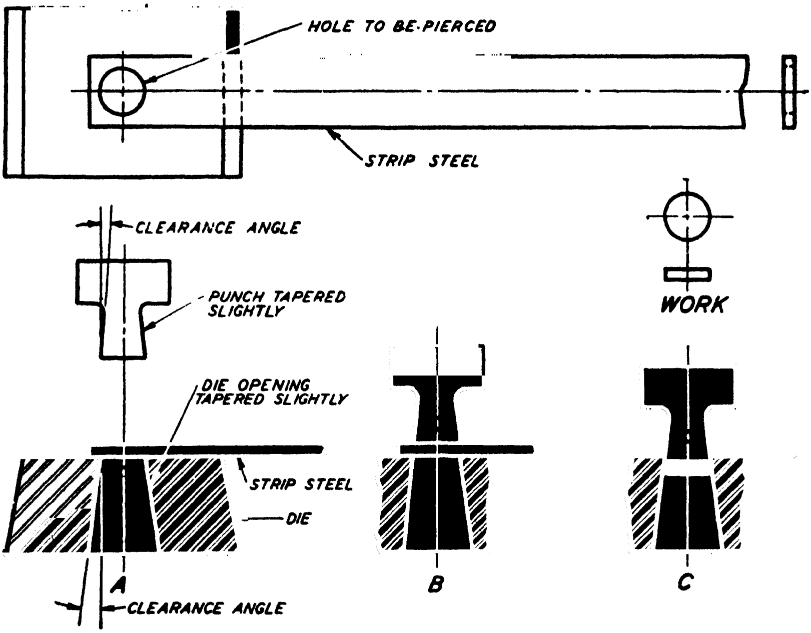


Fig. 6 Plain Perforating Die for Punching Strip Steel, and Work Produced

Progressive Piercing and Blanking Dies. Progressive piercing and blanking dies are extensively used in producing stampings. They are termed "progressive" because of the sequence of operations performed in a single die. Usually the perforating station in a die is the first operation. Then notching, blanking, or cutting off is performed. In Fig. 7 a rectangular piece with an elongated slot punched in it is made from a piece of flat brass. The piercing punch and blanking punch are shown in section. The stripper is a solid type and is mounted directly to the top of the die section in the die. A guide is provided at the rear of the die so that when the strip is traversed through the die it will be guided in the correct position for performing the various operations. The blanking punch is provided with a pilot so that it will locate in the elongated slot produced by the piercing punch.

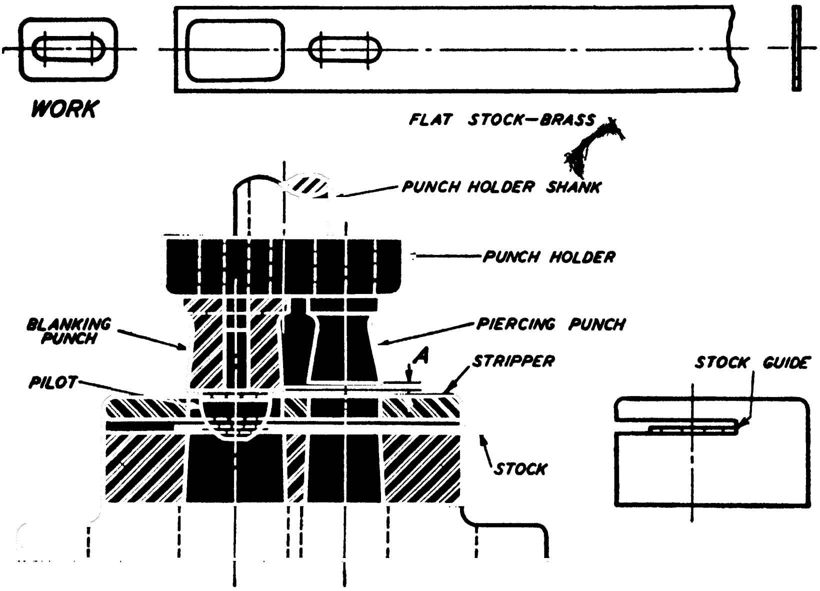


Fig. 7. Simple Progressive Piercing and Blanking Die, and Work Produced

On progressive dies, automatic finger stops are usually provided so that the stock will be pushed into the die to a stop; then the press is started. As the ram rises, the stock is released from the stop and is fed in to the required distance.

On some types of progressive dies it is necessary to provide pilot holes on the sides of the stock. These holes engage pilots that are designed and built into the die. They are progressive dies, but are often termed *3-4* (or more) *station dies.* Frequently as many as 7 or 8 operations are performed in one die.

In designing a progressive pierce and blank die for a segment roller shaft bearing bracket that must be produced in large quantities, Fig. 8, it was necessary to design a die that would produce these parts in the most economical way. The piece part requires material that is .0937″ or 3/32″ thick. This material is available in all standard widths, but it was found that the most economical way to handle this material through the die was to shear this stock to 1⅝″ wide by 3 feet long. Therefore the blank layout shown in Fig. 9 was made. This allowed the least possible amount of waste. As its layout shows, the first operation was piercing one .136″ diameter hole, the next station in this die was piercing an additional .136″ hole and the .429″ hole. The next station of the die blanks the outside contour of the piece part. By referring again to the piece part drawing, Fig. 8, it will be noted that the distances between these various pierced holes are given in decimal dimensions. The .429″ pierced hole is finally finished by reaming in a drill press. This means that this piece part must be guided through the die by means of a pilot. The .136″ hole is used for a pilot hole in the die.

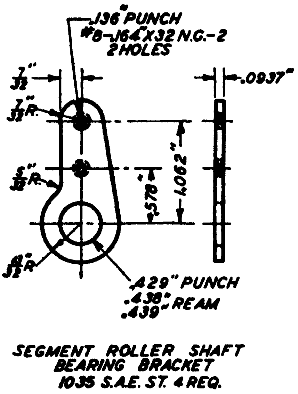


Fig. 8. Piece Part Produced in Punch Press

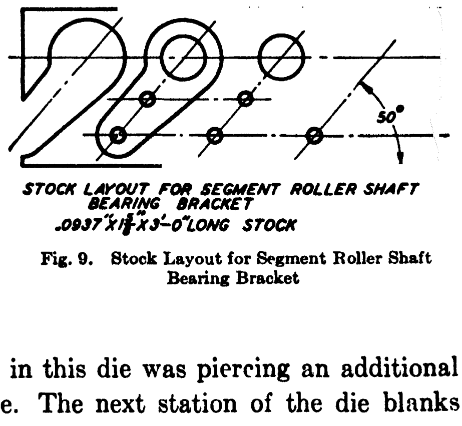

50°
STOCK LAYOUT FOR SEGMENT ROLLER SHAFT
BEARING BRACKET
.0937"X1⅝"X3'-0" LONG STOCK

Fig. 9. Stock Layout for Segment Roller Shaft Bearing Bracket

Fig. 10 presents a plan view and a front sectional view of a progressive piercing and blanking die for producing the part shown in Fig. 8. The upper view of this illustration shows the stock guide and the line *A*-*A* which is drawn through the center. The lower portion of this drawing shows a sectional view of the die taken through the cutting plane line *A-A*. The stock is illustrated by the heavy black line. The die set used is a commercial one and

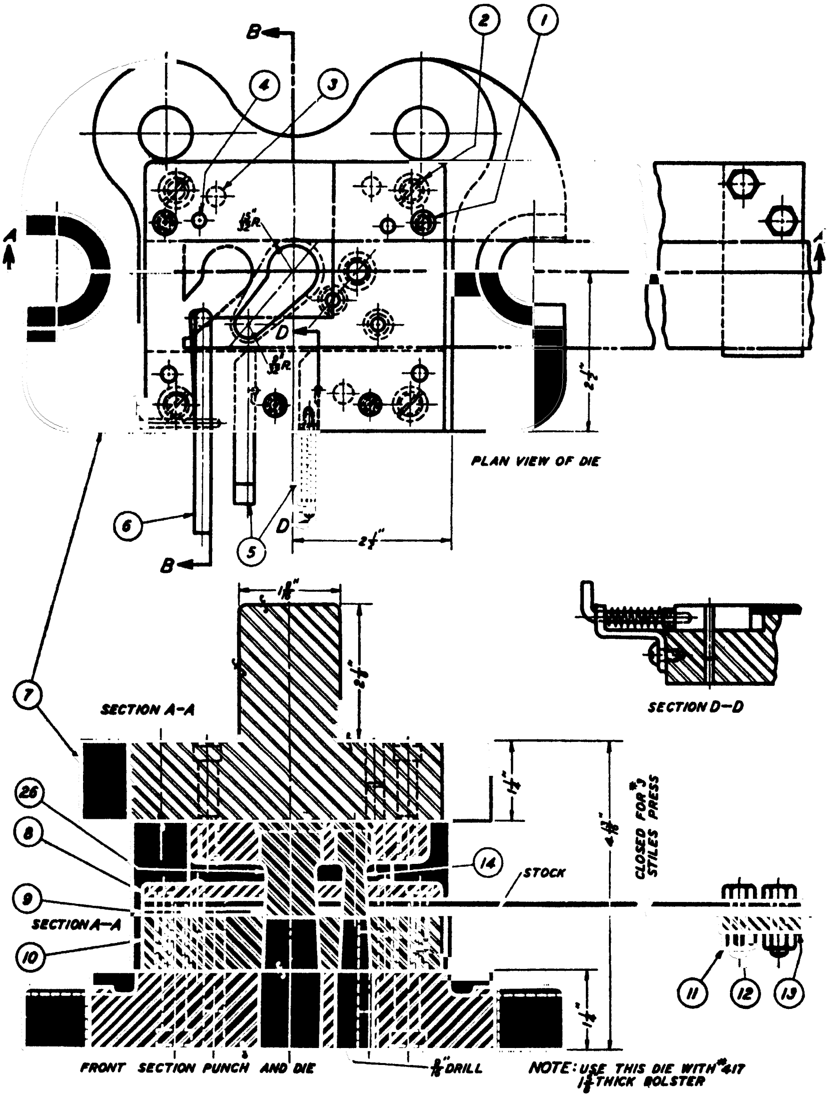

B
②
①
④
③
A
A
D
PLAN VIEW OF DIE
⑥
B
⑤
D
SECTION A-A
SECTION D-D
⑦
㉖
⑧
⑨
SECTION A-A
⑩
⑭
STOCK
CLOSED FOR #3 STILES PRESS
⑪
⑫
⑬
FRONT SECTION PUNCH AND DIE
DRILL
NOTE: USE THIS DIE WITH #417 THICK BOLSTER

Fig. 10. Plan and Front Sectional Views of a Progressive Piercing and Blanking Die

was purchased. Fig. 10 shows the location of the various details on the plan view of the die. Fig. 11 is the bottom view of the punch section, and the right end section of a die, with the location of the various details of the punch section of the die. The lower

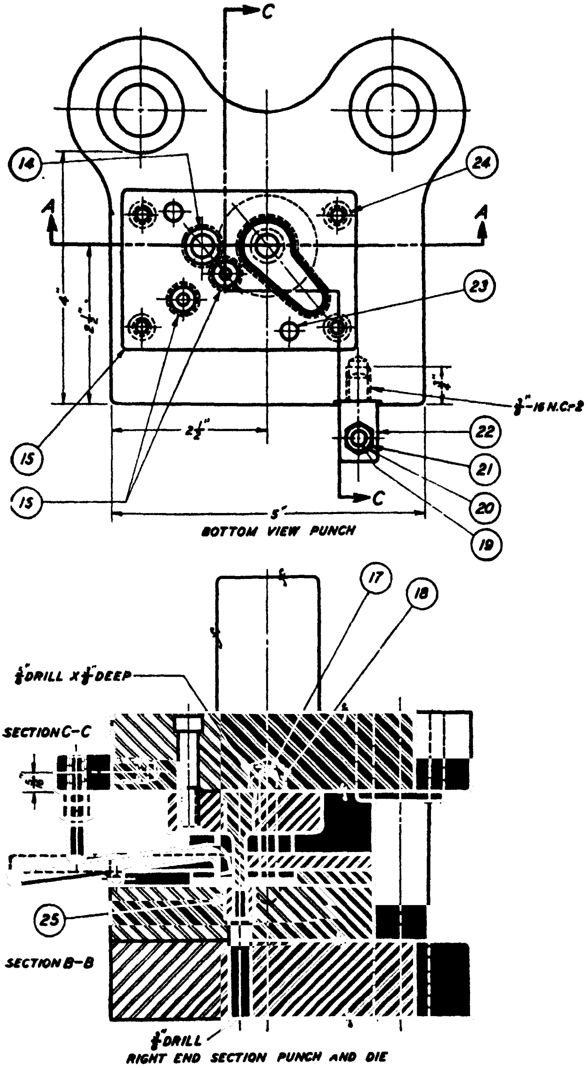


Fig. 11. Bottom View of Punch and Right-End Section of Die Shown in Fig. 10

portion of this illustration, which is sectioned, is a view taken through an interrupted cutting plane line *B-B*. By referring to

Fig. 10 the tool designer can note just where this section is taken. The dotted lines in the lower portion of the drawing shown in Fig. 11 show the action of the automatic stop. In this case the stop is released when the punch section of the die has perforated the stock. As soon as the ram is raised, the automatic stop is again in position and stops the stock at the correct point in the die. It will be noted that a leader-pin die set was selected in designing this die because

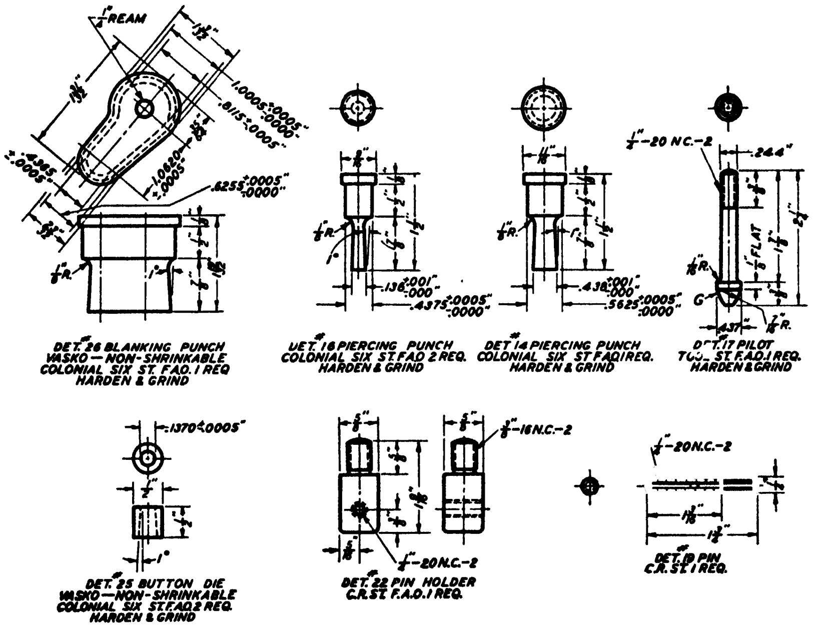


Fig. 12. Working Drawings for Die Shown in Figs. 10 and 11

these leader pins act as guides to assure proper alignment between the punch and die sections of the die. The use of leader-pin die sets eliminates considerable time and trouble in setting the dies in the punch press, as they prevent misalignment which possibly would damage the die.

Fig. 12 is a drawing illustrating the various details of construction of the die. Detail *26* is the blanking punch. This is designed to be made of nonshrinkable tool steel. It will be noted that one degree of angle is provided for clearance on the contour blanking punch.

Detail *16* shows a piercing punch, two of which are required.

These are made out of tool steel, 1° of clearance is provided, and they are hardened and ground to a decimal dimension .136" with a plus tolerance of .001" and a minus tolerance of .000". It will be noted that these punches are provided with a shoulder ⅛" deep for mounting in a punch plate.

Detail *25* shows a die insert or button die, as it is frequently called. It is made from a nonshrinkable tool steel and is hardened and ground. The inside diameter of this button die is ground to .137" diameter to provide a clearance of .001" between the punch and the die. Note that this clearance is only .001" because this piece part must be produced without the appreciable burr which would be caused by a larger amount of clearance between the punch and die sections. In designing dies, a small amount of clearance between punch and die often results in excessive breakage of punches and is not considered good practice; however, in the design of this die wherein the punches are readily removable, the small clearance can be tolerated. The other details shown on this illustration include the pilot; they are self-explanatory and their location can be determined by studying the drawing showing the assembly view of the die.

Fig. 13 shows the stock guide which is made of details *9, 11, 12,* and *13*. This stock guide is mounted on the die section so that when the 3-foot length of material is put into the die it will be supported properly. In many types of dies, stock guides are considered necessary.

Detail *8* is a stripper plate that is designed to be made out of cold-rolled steel; sufficient clearance for the punches must be provided. The stripper plate serves two purposes: first, to strip the stock from the punch; second, to guide the punches. This is very important when heavy material is being punched or blanked in a die.

Detail *15* is a punch plate in which the various perforating and blanking punches are mounted. This is designed to be made of a 1040 S.A.E. steel, as a cold-rolled steel would be entirely too soft and the side pressure might cause softer material to distort; therefore an alloy steel is specified.

Detail *10* is the die block. This is designed to be made out of a nonshrinkable oil-hardening tool steel. Due to the number

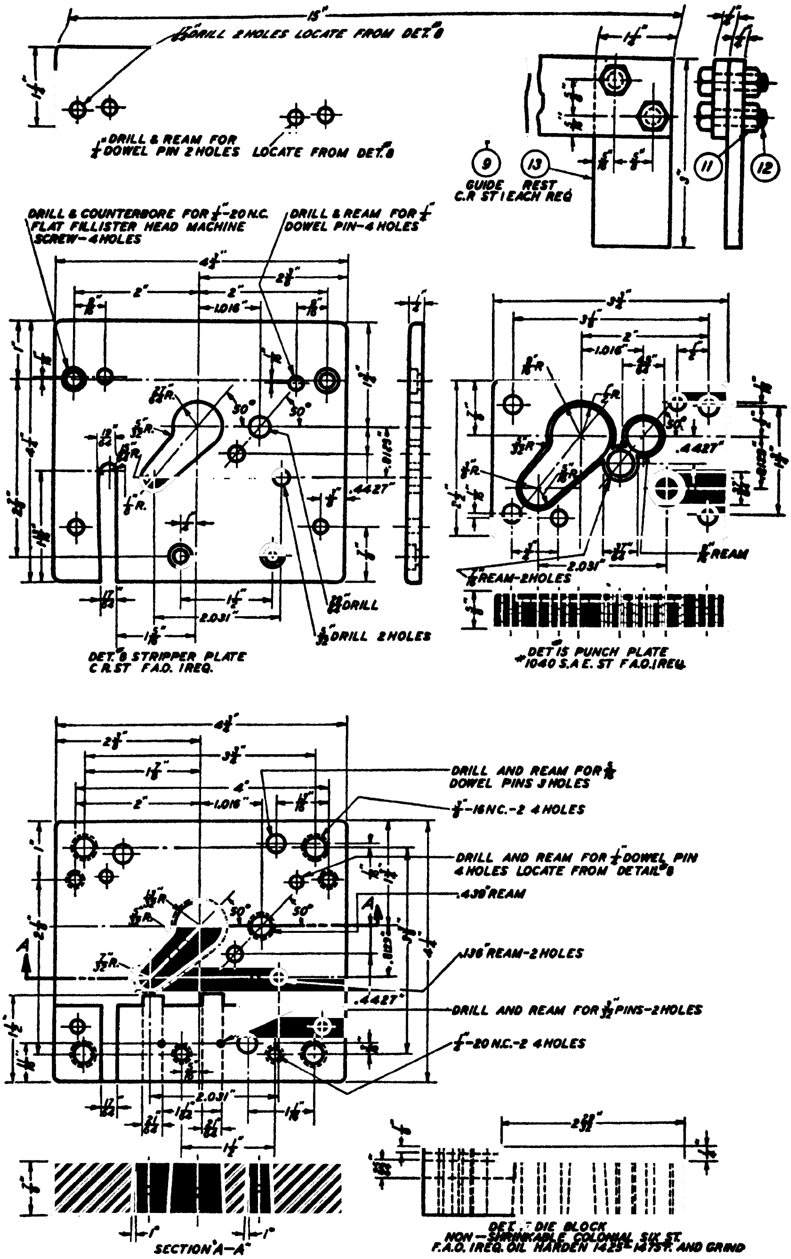
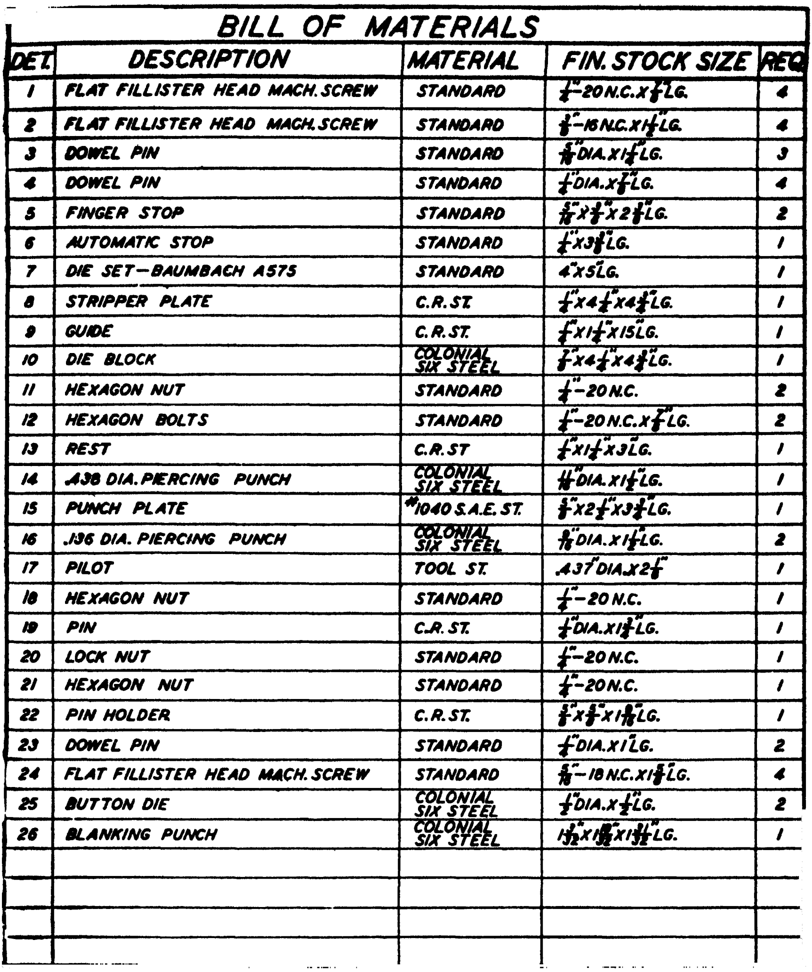

15"
DRILL 2 HOLES LOCATE FROM DET. 8
DRILL & REAM FOR DOWEL PIN 2 HOLES
LOCATE FROM DET. 8
9
13
GUIDE
REST
C.R ST 1 EACH REQ
11
12
DRILL & COUNTERBORE FOR ¼"-20 N.C. FLAT FILLISTER HEAD MACHINE SCREW-4 HOLES
DRILL & REAM FOR ¼" DOWEL PIN-4 HOLES
4½"
2"
2"
1.016"
50°
50°
.4427"
2.031"
DRILL
DRILL 2 HOLES
DET. 8 STRIPPER PLATE
C.R.ST F.A.O. 1 REQ.
1.016"
2"
.4427"
REAM
REAM-2 HOLES
2.031"
DET. 15 PUNCH PLATE
#1040 S.A.E. ST F.A.O. 1 REQ.
4½"
4"
2"
1.016"
DRILL AND REAM FOR DOWEL PINS 3 HOLES
-16 N.C.-2 4 HOLES
DRILL AND REAM FOR ¼" DOWEL PIN 4 HOLES LOCATE FROM DETAIL 8
.439" REAM
A
A
50°
50°
.136" REAM-2 HOLES
.4427"
DRILL AND REAM FOR PINS-2 HOLES
¼"-20 N.C.-2 4 HOLES
2.031"
SECTION "A-A"
DET. 7 DIE BLOCK
NON-SHRINKABLE COLONIAL SIX ST.
F.A.O. 1 REQ. OIL HARDEN 1425°-1475°F. AND GRIND

Fig. 13. Working Drawings of Die Block, Punch Plate etc., Fig. 10



BILL OF MATERIALS				
DET.	DESCRIPTION	MATERIAL	FIN. STOCK SIZE	REQ
1	FLAT FILLISTER HEAD MACH. SCREW	STANDARD	1/4"-20 N.C. X 3/4" LG.	4
2	FLAT FILLISTER HEAD MACH. SCREW	STANDARD	3/8"-16 N.C. X 1 1/4" LG.	4
3	DOWEL PIN	STANDARD	5/16" DIA. X 1 1/4" LG.	3
4	DOWEL PIN	STANDARD	1/4" DIA. X 3/4" LG.	4
5	FINGER STOP	STANDARD	5/16" X 3/4" X 2 3/4" LG.	2
6	AUTOMATIC STOP	STANDARD	1/4" X 3 3/4" LG.	1
7	DIE SET—BAUMBACH A575	STANDARD	4" X 5" LG.	1
8	STRIPPER PLATE	C.R. ST.	1/4" X 4 1/4" X 4 1/4" LG.	1
9	GUIDE	C.R. ST.	1/4" X 1 1/4" X 15" LG.	1
10	DIE BLOCK	COLONIAL SIX STEEL	7/8" X 4 1/4" X 4 1/4" LG.	1
11	HEXAGON NUT	STANDARD	1/4"-20 N.C.	2
12	HEXAGON BOLTS	STANDARD	1/4"-20 N.C. X 7/8" LG.	2
13	REST	C.R. ST.	1/4" X 1 1/4" X 3" LG.	1
14	.438 DIA. PIERCING PUNCH	COLONIAL SIX STEEL	11/16" DIA. X 1 1/2" LG.	1
15	PUNCH PLATE	#1040 S.A.E. ST.	5/8" X 2 1/4" X 3 1/4" LG.	1
16	.136 DIA. PIERCING PUNCH	COLONIAL SIX STEEL	5/16" DIA. X 1 1/2" LG.	2
17	PILOT	TOOL ST.	.437" DIA. X 2 5/8"	1
18	HEXAGON NUT	STANDARD	1/4"-20 N.C.	1
19	PIN	C.R. ST.	1/4" DIA. X 1 3/4" LG.	1
20	LOCK NUT	STANDARD	1/4"-20 N.C.	1
21	HEXAGON NUT	STANDARD	1/4"-20 N.C.	1
22	PIN HOLDER	C.R. ST.	5/8" X 5/8" X 1 5/16" LG.	1
23	DOWEL PIN	STANDARD	1/4" DIA. X 1" LG.	2
24	FLAT FILLISTER HEAD MACH. SCREW	STANDARD	5/16"-18 N.C. X 1 5/8" LG.	4
25	BUTTON DIE	COLONIAL SIX STEEL	1/4" DIA. X 1/2" LG.	2
26	BLANKING PUNCH	COLONIAL SIX STEEL	1 9/32" X 1 13/32" X 1 31/32" LG.	1

Fig. 14. Bill of Materials for the Die Shown in Figs. 10 and 11

of holes and openings in this die block, it is important that a non-shrinkable tool steel be specified to prevent distortion and warping during the heat treatment.

Fig. 14 is a bill of materials for the completed die. By referring to the assembly drawing and identifying the various detail drawings, it will be seen that the finished stock size is given in each instance. All materials are plainly specified so that the tool room will have no difficulty in selecting the correct materials or items for the making of a die of this kind.

Simple Forming Dies. To put a right-angle bend in piece parts, a vee die is generally used. Fig. 15 illustrates a vee die for putting a 90° bend in the piece part which is shown as a developed blank by Fig. 16 where the formed piece part is shown at *B*. By referring again to Fig. 15 it will be seen that this design of die consists of a vee punch mounted in the punch holder and that there is a vee shaped in the die block on the die holder. A spring plunger is mounted in the die shoe to push the work up off the vee in the die section. It will be noted that the punch is designed to be made an 85° angle instead of the 90° angle which is shown by the piece part. This is due to the fact that there will be a certain amount of spring-back and if the forming punch were made to a 90° angle, the finished piece part would not be correct. This same design of die is often made for vee bends of considerable length. Usually the dies for doing a job of this kind would be designed to be used in a power brake. Vee dies of this type are also used for putting the multiple bends in sheet steel.

Cutoff and Forming Dies. When it is necessary to design a die to produce a large number of piece parts that have to be cut off and formed from strip stock, a die is usually designed similar to Fig. 17. It will be noted that this die is designed with a stock guide and the material is fed in from right to left of the die. The cutoff and forming is done at the same time. This is somewhat similar in principle to the vee die, except that the forming section of the die is mounted on springs and, after the cutting-off operation takes place, the piece is allowed to pass on through on the forming block until it bottoms. This forms the correct bend. A knockout pin, detail *10,* is provided with a spring, detail *9,* for pushing the piece part off the forming punch, detail *16* of Fig. 18. The piece part, which is a tray arm-latch, is shown by *A*. This die operates very fast, and designs similar to this can be used for a number of piece parts that are cut off and formed in the one operation.

Progressive Piercing and Blanking Dies. Fig. 19 is the design of a die to produce the piece part shown at *A1* in Fig. 20. It is a bracket head made out of hard cold-rolled steel. In this part it is necessary to punch 4 holes .201″ plus or minus .001″ diameter, and one hole .312″ plus or minus .001″. This hole is afterwards

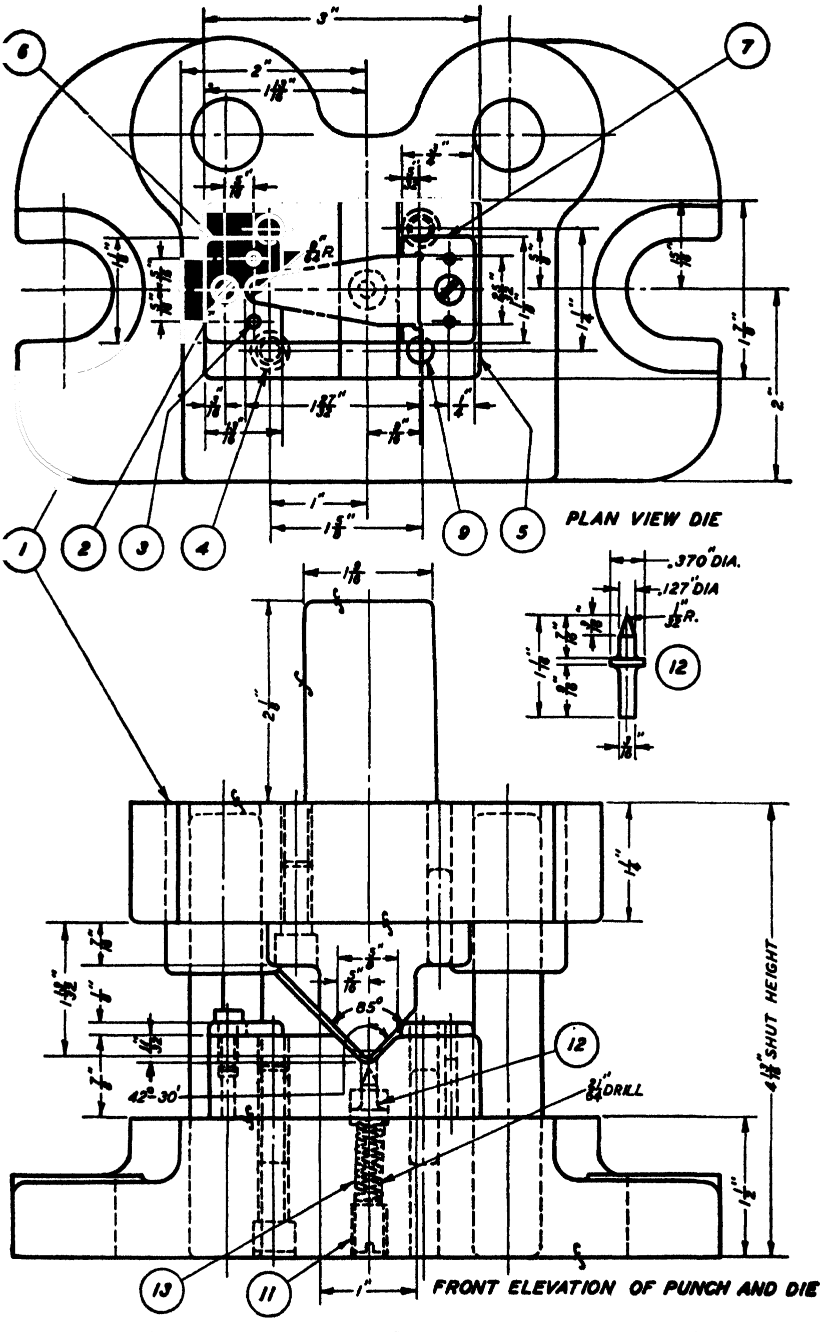
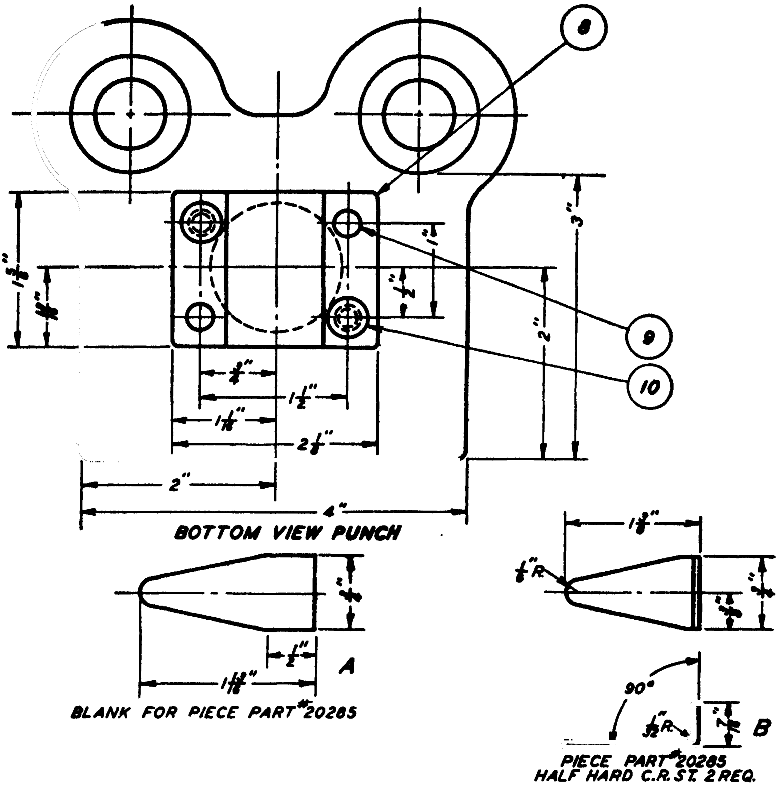


Fig. 15. Die to Form Piece Part No. 20285 Having a Right-Angle Bend



DET.	DESCRIPTION	MATERIAL	REQ.	STOCK SIZE
13	SPRING	SPRING ST.	1	MAKE TO SUIT
12	KNOCKOUT PIN	DRILL ROD	1	1/8" DIA. X 1 1/16"
11	HEADLESS SET SCREW	STANDARD	1	3/8"-16 N.C. X 1/2"
10	FLAT FILL. HEAD MACH. SCREW	STANDARD	2	5/16"-18 N.C. X 3/4"
9	DOWEL PIN	STANDARD	4	1/4" X 1"
8	PUNCH	TOOL STEEL	1	1 13/32" X 1 5/8" X 2 1/8"
7	GAGE BLOCK	TOOL STEEL	1	1/8" X 3/4" X 1 1/8"
6	GAGE BLOCK	TOOL STEEL	1	1/8" X 13/16" X 1 1/8"
5	DIE BLOCK	TOOL STEEL	1	7/8" X 1 7/8" X 3"
4	FLAT FILL. HEAD MACH. SCREW	STANDARD	2	5/16"-18 X 1 5/8"
3	DOWEL PIN	STANDARD	4	1/4" X 3/8"
2	FLAT FILL. HEAD MACH. SCREW	STANDARD	2	#10-.190"-24 N.C. X 1/2"
1	DIE SET	SEMI-STEEL	1	

3"X4" BAUMBACH DIE SET NUMBER A32
PRESS NO. 2 STILES BOLSTER #204 1 1/16" THICK
V— FORMING DIE

Fig. 16. Bottom View of Punch, etc., Fig. 15

countersunk in a drill press. It will be noted that this piece part, in addition to the contour, has a 20° bend or angle; this requires

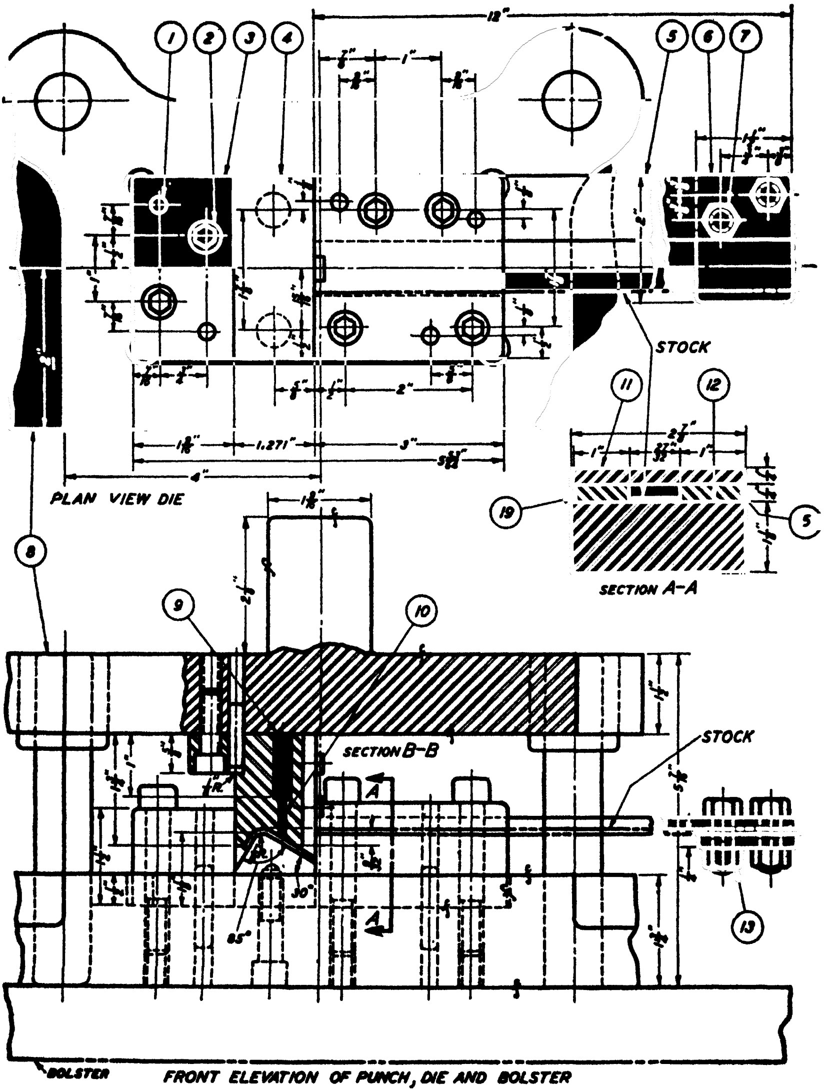
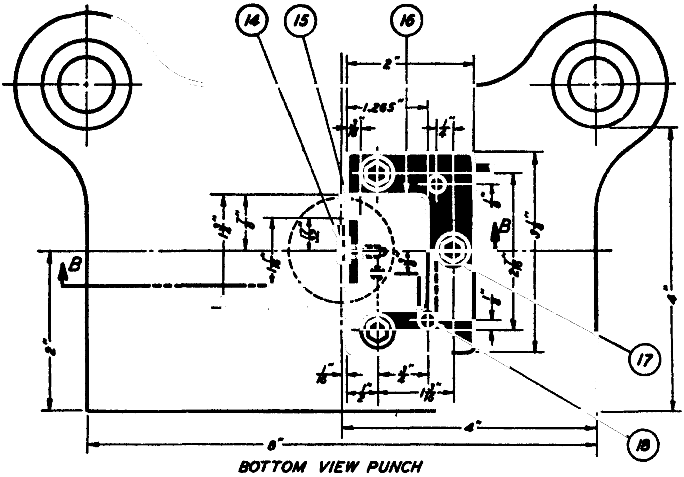
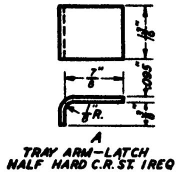
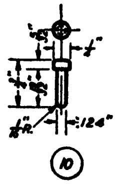


Fig. 17. Cut-off and Forming Die for Making a Tray Arm-Latch

an additional forming die. The upper part of Fig. 19 shows the plan view of the die. Various sections have been taken through this to show the construction. The bottom drawing is a sectional view *A-A*. This is taken directly through the center of the die and shows the important positions of the various perforating







BILL OF MATERIALS

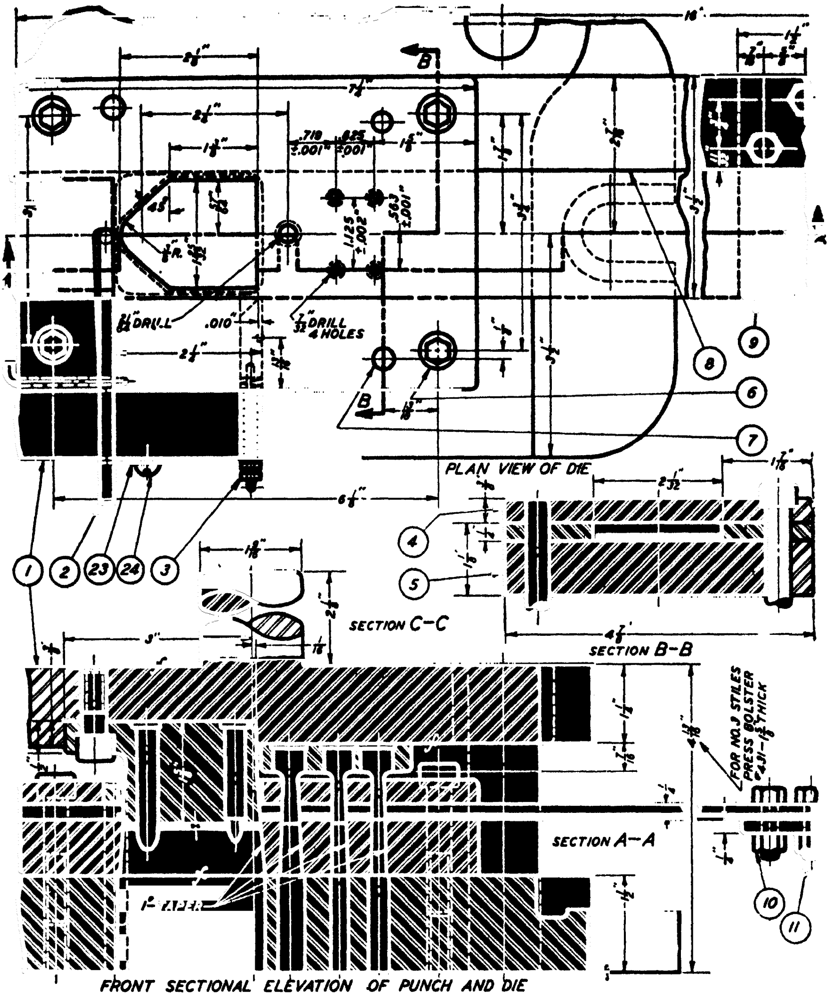
DET.	DESCRIPTION	MATERIAL	REQ	FIN. STK. SIZE
1	DOWEL PIN	STANDARD	5	1/4"X1 1/4"
2	SOCKET HEAD SCREW	STANDARD	6	3/8"-16X2 1/4"
3	GAGE BLOCK	ONTARIO DIE STEEL	1	1 1/2"X1 9/16"X2 7/8"
4	FORMING DIE	ONTARIO DIE STEEL	1	1 1/8"X1.271"X2 7/8"
5	GUIDE	C.R. STEEL	1	1/4"X1"X12"
6	REST PLATE	C.R. STEEL	1	1/4"X1 1/2"X2"
7	HEXAGON HEAD BOLT	STANDARD	2	5/16"-18X7/8"
8	DIE SET—ADVANCE ST'D.	BAUMBACH	1	4"X6"—A659
9	SPRING	SPRING ST.	1	MAKE TO SUIT
10	KNOCKOUT PIN	DRILL ROD	1	1/4"X3/4"
11	STRIPPER PLATE	C.R. STEEL	1	1/4"X2 7/8"X3"
12	BLOCK	ONTARIO DIE STEEL	1	1 1/8"X2 7/8"X3"
13	HEXAGON NUT	STANDARD	2	5/16-18
14	FLAT FILL. HEAD SCREW	STANDARD	2	#10-.190"-32X1/2"
15	SHEAR	ONTARIO DIE STEEL	1	3/16"X1 1/16"X1 3/4"
16	FORMING PUNCH	ONTARIO DIE STEEL	1	1 3/4"X2"X3 1/8"
17	SOCKET HEAD SCREW	STANDARD	3	5/16"-18X1"
18	DOWEL PIN	STANDARD	2	1/4"X1"
19	FILLER PLATE	C.R. STEEL	1	1/4"X1"X3"

USED ON #2 BLISS PRESS #902X1 1/8" THICK BOLSTER

CUTOFF AND FORMING DIE

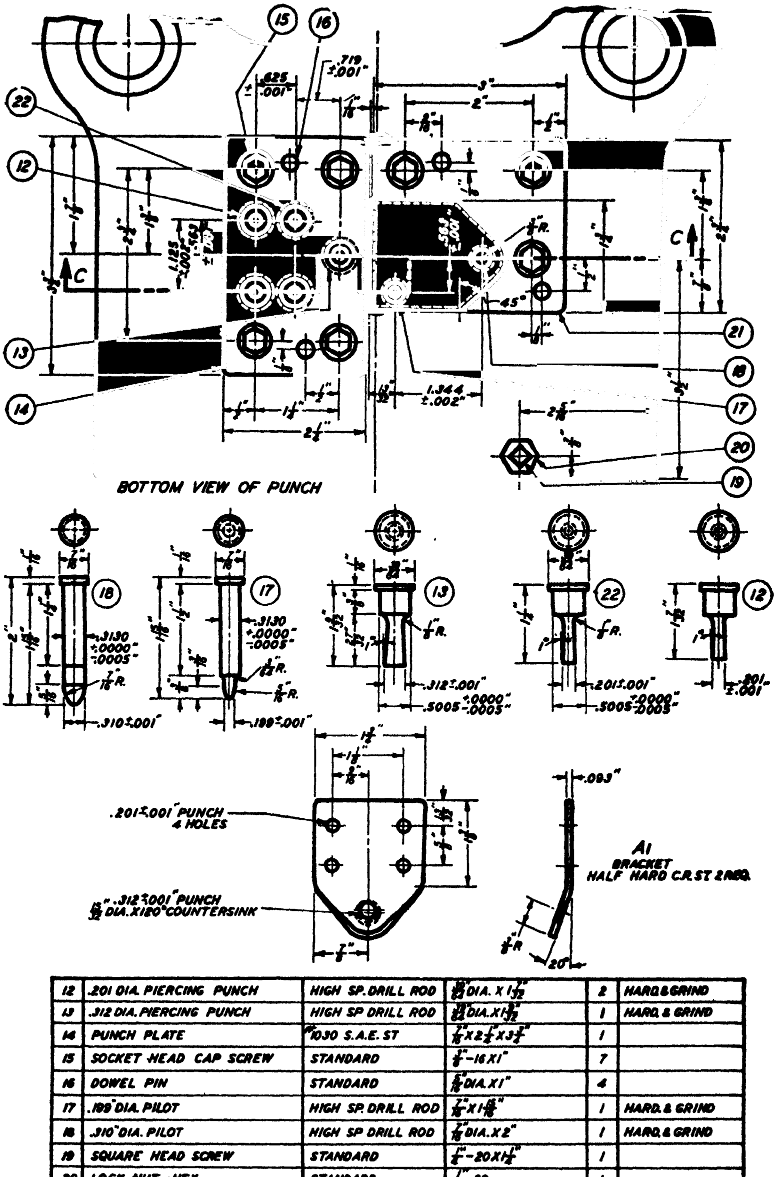
Fig. 18. Bottom View of Punch Shown in Fig. 17

punches and the pilots. A stock guide is provided and the material traverses through the die from right to left. The four .201" holes are punched at the first station in the die. The stock is then



1	DIE SET—BAUMBACH	SEMI-STEEL	6"X9"—A1655	1	
2	AUTOMATIC STOP	STANDARD		1	
3	FINGER STOP	STANDARD		1	
4	STRIPPER PLATE	#1030 S.A.E. ST	3/8"X4 7/8"X7 1/2"	1	
5	DIE BLOCK	COLONIAL 6 STEEL	1 1/8"X4 7/8"X 7 1/2"	1	HARD & GRIND
6	SOCKET HEAD CAP SCREW	STANDARD	3/8"-16X2"	4	
7	DOWEL PIN	STANDARD	3/8"X2 1/4"	3	
8	GUIDE	C.R. STEEL	1/4"X1 11/16"X16"	1	
9	STOCK REST	C.R. STEEL	1/4"X1 1/2"X3 1/2"	1	.
10	HEXAGON NUT	STANDARD	1/4"-20	2	
11	HEXAGON HEAD BOLT	STANDARD	1/4"-20X7/8"	2	

Fig. 19. Die to Blank and Pierce Holes in Bracket *A1*, Shown in Fig. 20



12	.201 DIA. PIERCING PUNCH	HIGH SP. DRILL ROD	$\frac{13}{64}$" DIA. X $1\frac{7}{32}$"	2	HARD.&GRIND
13	.312 DIA. PIERCING PUNCH	HIGH SP DRILL ROD	$\frac{21}{64}$" DIA.X$1\frac{3}{32}$"	1	HARD. & GRIND
14	PUNCH PLATE	#1030 S.A.E. ST	$\frac{7}{16}$"X$2\frac{1}{4}$"X$3\frac{1}{4}$"	1	
15	SOCKET HEAD CAP SCREW	STANDARD	$\frac{1}{4}$"-16X1"	7	
16	DOWEL PIN	STANDARD	$\frac{5}{16}$" DIA.X1"	4	
17	.199" DIA. PILOT	HIGH SP. DRILL ROD	$\frac{7}{16}$"X$1\frac{15}{16}$"	1	HARD.& GRIND
18	.310" DIA. PILOT	HIGH SP DRILL ROD	$\frac{7}{16}$" DIA.X2"	1	HARD.& GRIND
19	SQUARE HEAD SCREW	STANDARD	$\frac{1}{4}$"-20X$1\frac{1}{2}$"	1	
20	LOCK NUT-HEX.	STANDARD	$\frac{1}{4}$"-20	1	
21	BLANKING PUNCH	COLONIAL 6 STEEL	$1\frac{5}{8}$"X$2\frac{3}{4}$"X$3\frac{1}{16}$"	1	HARD.& GRIND
22	.201 DIA. PIERCING PUNCH	HIGH SP. DRILL ROD	$\frac{13}{64}$" DIA.X$1\frac{1}{4}$"	2	HARD.& GRIND
23	AUTOMATIC STOP SPRING	SPRING STEEL	MAKE TO SUIT	1	
24	ROUND HEAD MACH. SCREW	STANDARD	$\frac{1}{4}$"-20X$\frac{1}{2}$"	1	

Fig. 20. Bottom View of Punch which is Shown in Fig. 19

pushed on through the die, the contour of the piece is blanked, and the cutoff operation takes place. Pilots are provided at this station so that the piece will be held in the proper position for the blanking operation. In Fig. 20 is a bottom view of the punch section of the die, together with the details of the perforating punches and the pilots.

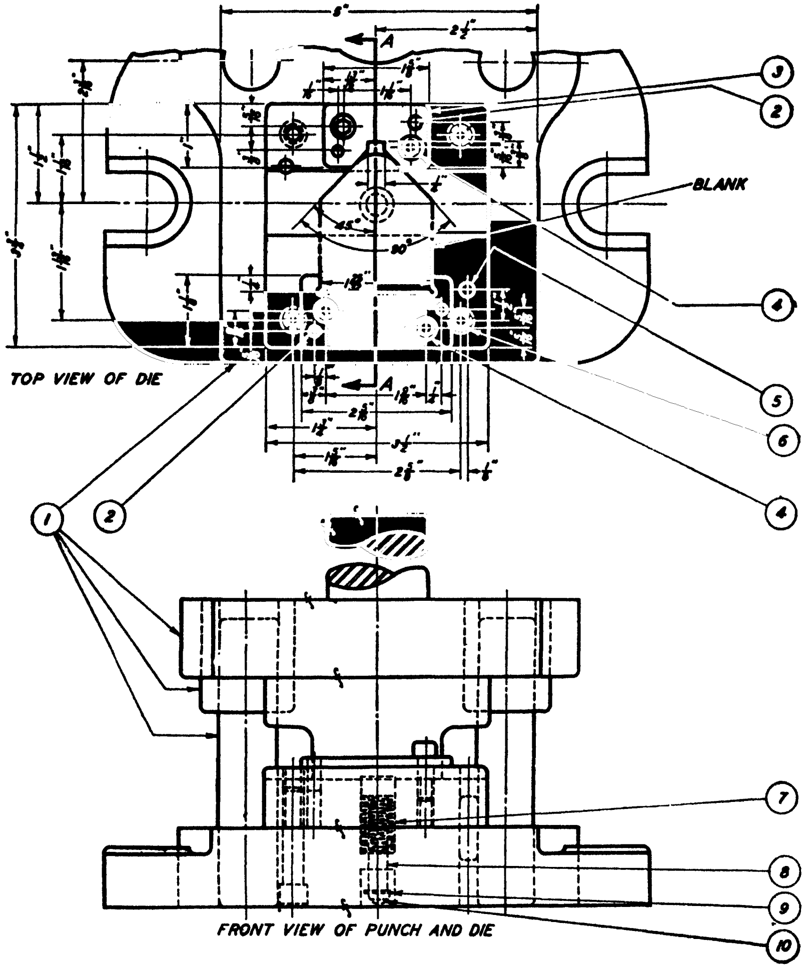
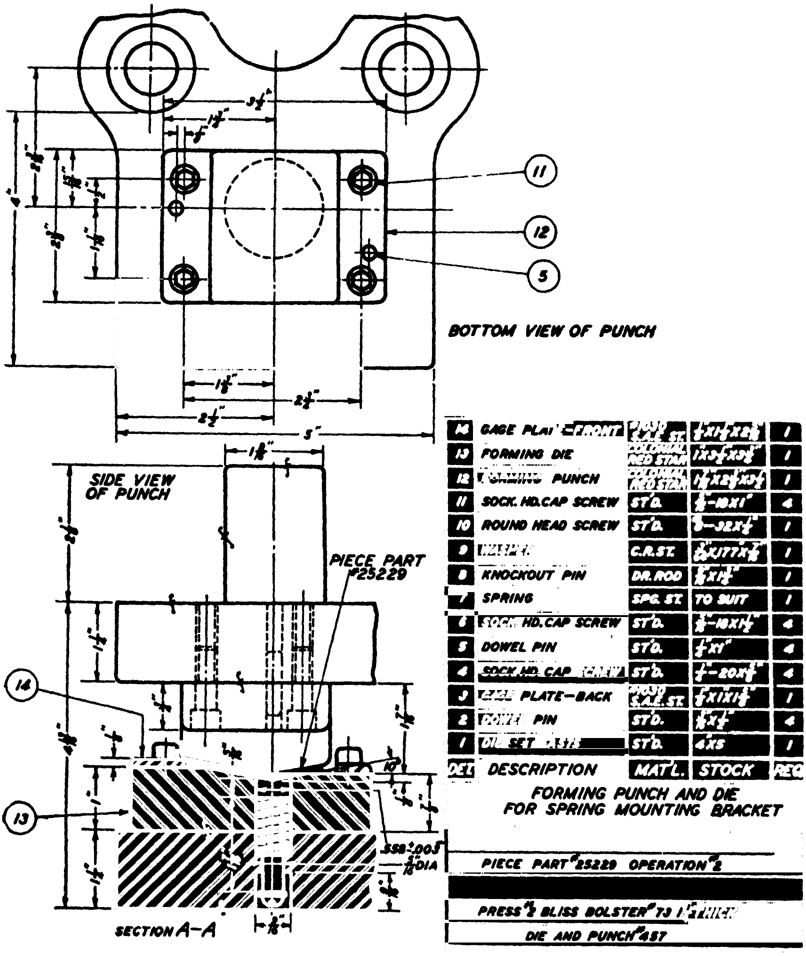


Fig. 21. Die for Forming 20° Bend on Bracket *A1* of Fig. 20

For forming the 20° bend on this piece part, a forming die, Fig. 21, is designed. The top view of the die is shown in the upper portion of the drawing. It will be noted that this piece is nested in the die, and a vee-shaped gage plate, detail *3*, is used to locate the angular section of the piece part. An additional gage plate,



DET.	DESCRIPTION	MAT'L.	STOCK	REQ.
14	GAGE PLATE—FRONT	#1030 S.A.E. ST.	1/4X1 1/4X2 3/8	1
13	FORMING DIE	COLONIAL RED STAR	1X3 1/2X5 1/4	1
12	FORMING PUNCH	COLONIAL RED STAR	1 1/8X2 1/4X3 1/4	1
11	SOCK. HD. CAP SCREW	ST'D.	1/4-20X1"	4
10	ROUND HEAD SCREW	ST'D.	8-32X1/4	1
9	WASHER	C.R.ST.	1/16X1.177X1/4	1
8	KNOCKOUT PIN	DR. ROD	1/4X1 1/2"	1
7	SPRING	SPG. ST.	TO SUIT	1
6	SOCK. HD. CAP SCREW	ST'D.	1/4-20X1 1/2"	4
5	DOWEL PIN	ST'D.	1/4X1"	4
4	SOCK. HD. CAP SCREW	ST'D.	1/4-20X1 1/4"	4
3	GAGE PLATE—BACK	#1030 S.A.E. ST.	1/4X1X1 1/4"	1
2	DOWEL PIN	ST'D.	3/16X1/2"	4
1	DIE SET #1375	ST'D.	4X5	1

FORMING PUNCH AND DIE
FOR SPRING MOUNTING BRACKET

PIECE PART #25229 OPERATION #2

[redacted]

PRESS #2 BLISS BOLSTER #73 1 1/2 THICK

DIE AND PUNCH #457

Fig. 22. Bottom View of Punch, Fig. 21

detail *14* of Fig. 22, is used for locating the rear portion of the piece part in the die. A knockout pin, detail *8*, is put in the bottom portion of the die section to push the piece part off the forming section of the die.

Fig. 22 shows the detailed construction of the forming punch and a cross section of the die. By studying these drawings the tool designer will obtain a very good idea of this type of design.

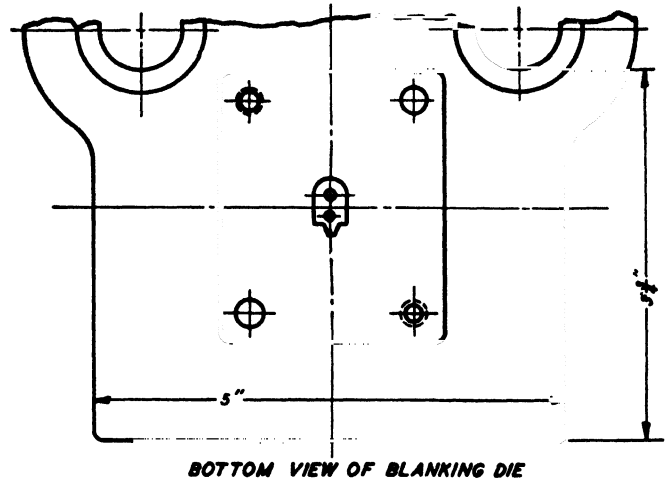
Compound Blanking and Piercing Dies. This type of die is generally designed to produce piece parts that must be perfectly flat and made to very accurate dimensions. In the lower part of Fig. 23 is shown a piece part that has two holes perforated in it in addition to a radius on one end and an angular tongue on the other. In this same drawing is a bottom view of the blanking die.

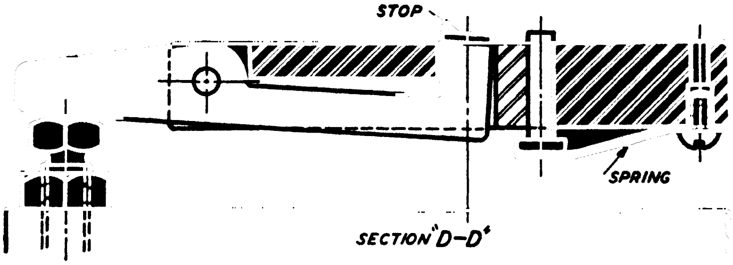
In Fig. 24 is shown the top view of the blanking punch, together with the automatic stop. This stop is designed to stop the material at the right position so that there will be no excessive waste of material. The front view of the punch and die shown in this drawing also contains the shut height of the die, which is 5″, and illustrates the stock passing through the die from right to left.

In the upper part of Fig. 25 is shown the top view of the blanking punch. This takes care of the contour of the piece part. The lower part of this drawing, section *A-A*, shows the punch and die and the action of the perforating punches in piercing the two holes required in this piece part.

Compound dies differ from other types of dies, as the blanking punch is located in the die section or lower part of the die. Through the blanking punch, clearance holes are machined so that the slugs from the perforators will pass out through the bottom portion of the die shoe. Fig. 26 is a drawing showing the details of construction of this die, with sectional views illustrating the action of the perforating punches and the blanking punch.

Designing compound dies is somewhat complicated and the tool designer must make sure that the design of the die is such that there will not be any excessively thin cross sections that would cause breakage. At the present time there is a wide variety of materials from which stampings are made and it is essential that the tool designer select the right steels for making the dies. The use of high-speed steel in designing tools has been increasing of late years, also other tool steels have been developed that permit the designing of dies to produce parts that only a few years ago were considered impossible. The various designs of dies that have been discussed in the preceding pages are only a limited outline of the possibilities of this type of die design; but with this knowl-





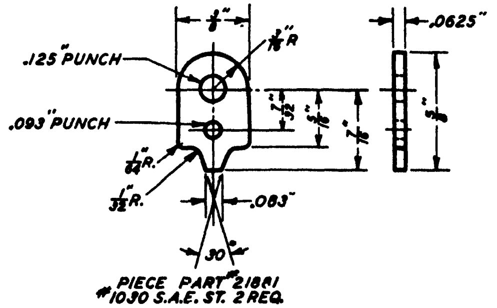


Fig. 23. Bottom View of Punch, Fig. 24

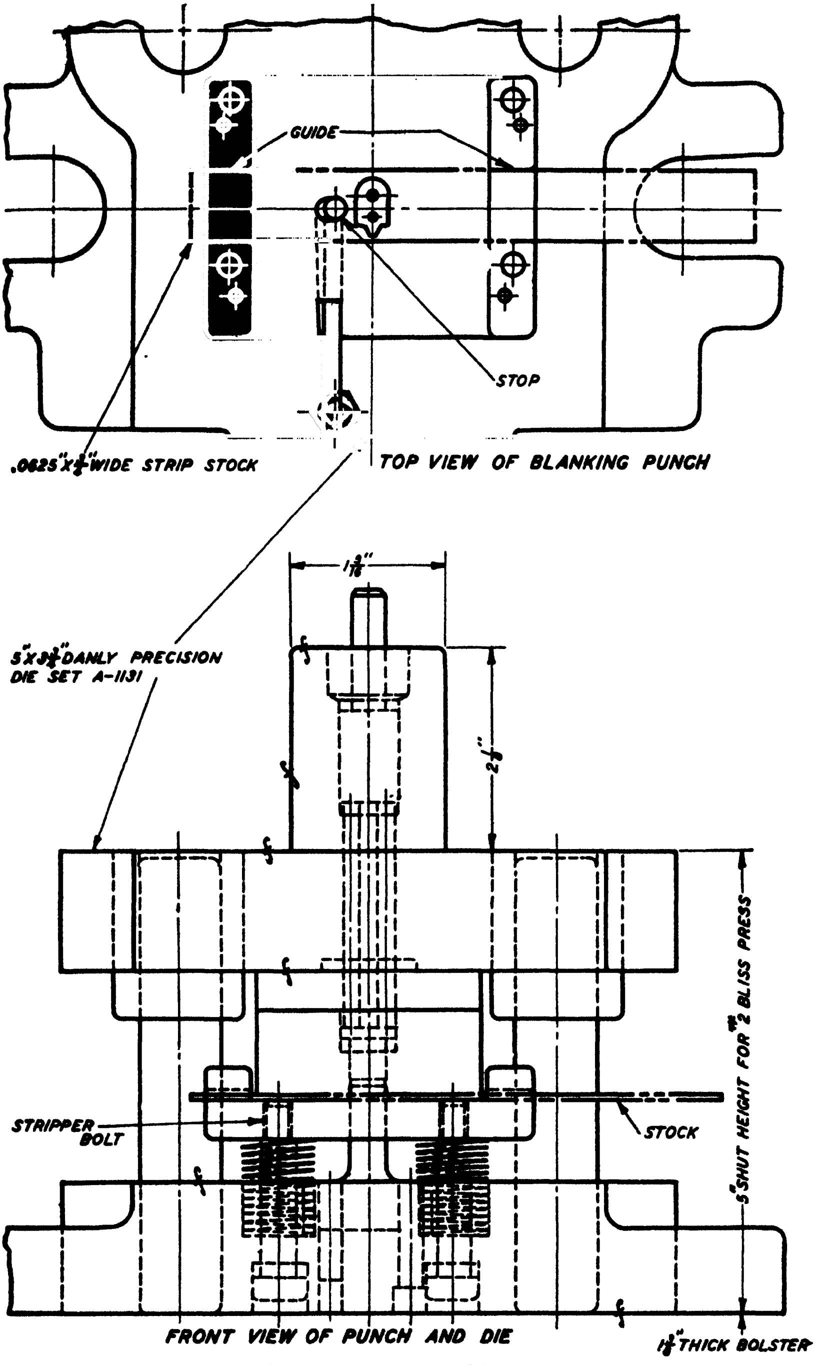
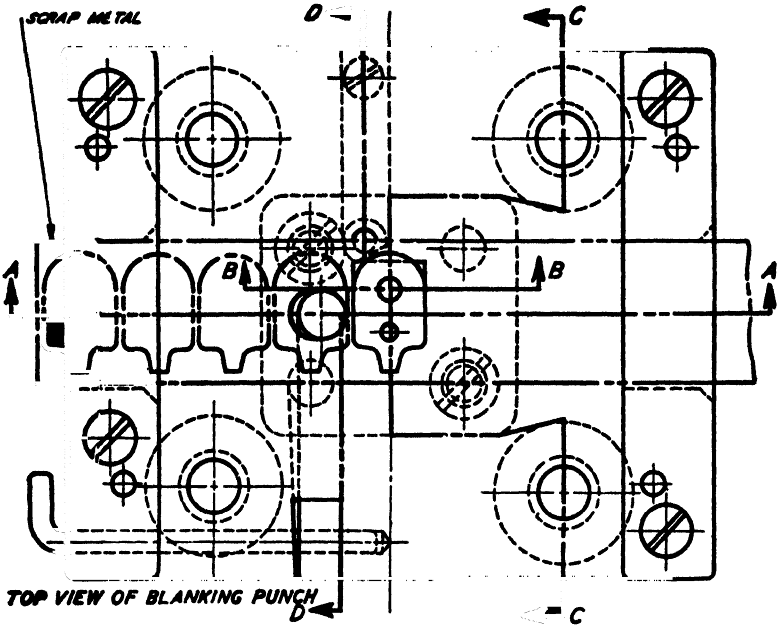
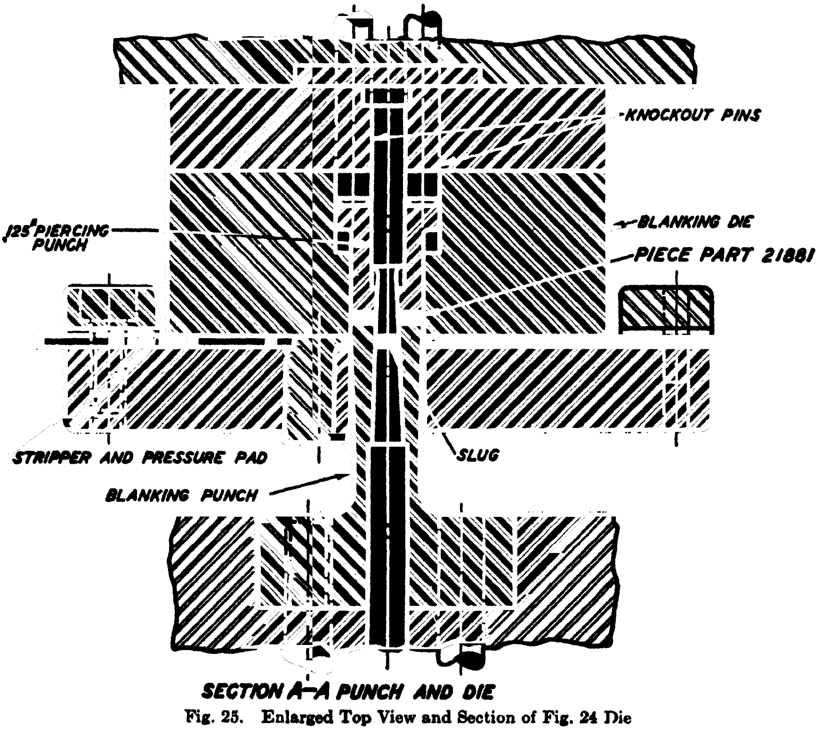

GUIDE
STOP
.0625" X ½" WIDE STRIP STOCK
TOP VIEW OF BLANKING PUNCH
1 3/16"
2 1/8"
5" X 3½" DANLY PRECISION DIE SET A-1131
STRIPPER BOLT
STOCK
5" SHUT HEIGHT FOR #2 BLISS PRESS
FRONT VIEW OF PUNCH AND DIE
1½" THICK BOLSTER

Fig. 24. Compound Blanking and Piercing Die for Piece Part No. 21681

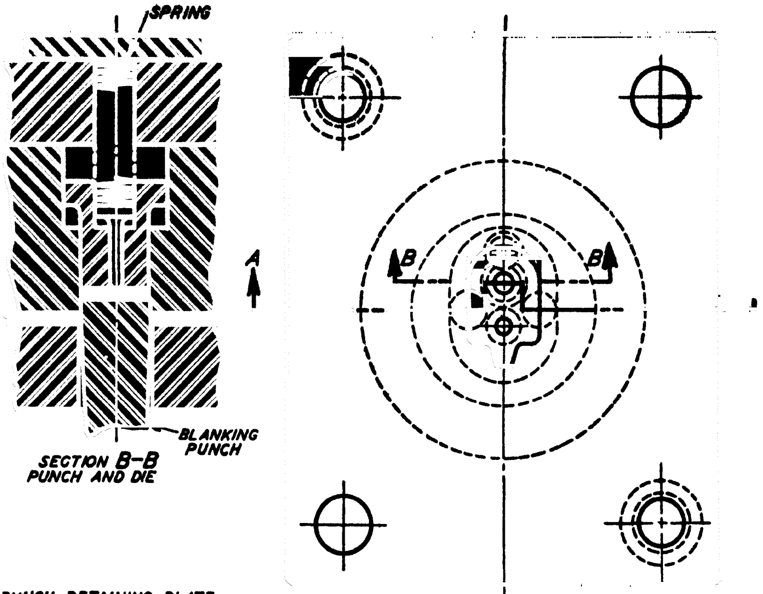


TOP VIEW OF BLANKING PUNCH



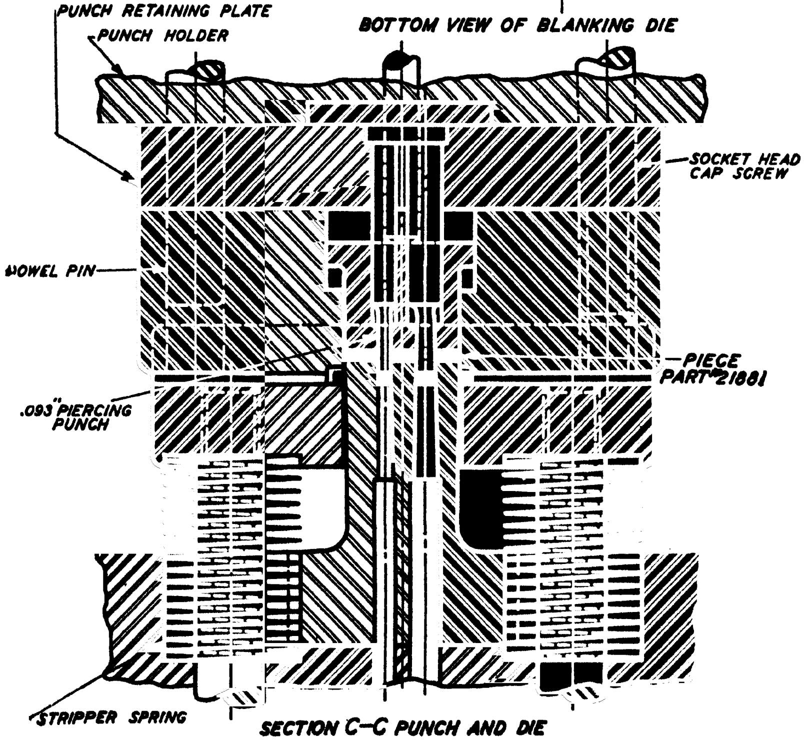
SECTION A-A PUNCH AND DIE

Fig. 25. Enlarged Top View and Section of Fig. 24 Die



SECTION B-B PUNCH AND DIE

BOTTOM VIEW OF BLANKING DIE



SECTION C-C PUNCH AND DIE

Fig 26. Enlarged Bottom View of Punch and Enlarged Sections at B-B and C-C

edge as a background, the designers will be able to assimilate the many new ideas that develop in the daily work of the designer.

Drop-Forging Dies. The designing of drop-forging dies to produce piece parts that are made of steel forgings requires considerable experience. These dies are made by a combination of punch-press dies and the process of molding. Drop-forging dies consist of two parts, the upper and the lower die. In designing these dies certain definite principles must be followed in order to produce good forgings. Steels used in making dies for forgings generally contain .60% to .85% carbon. Other alloy steels, such as hot-work steels, are also used for such dies. The designer must allow sufficient metal in the die sections so that when the impression is put into the die the correct amount of material will be left in the die sections and the pressure exerted in forging the piece parts will not cause distortion of the dies themselves.

Proper draft must be provided in the die so that there will be no sticking of the piece parts in the drop-forging dies. To properly design drop-forging dies, the tool designer should obtain a working knowledge of drop-forging practice; that is, the actual forging of metal in the shop. This is essential, as it is practically impossible for a tool designer without this experience to design drop-forging dies properly. The factors in designing drop-forging dies are somewhat similar to those for other types of dies. The hammer in which the dies are going to be used must be taken into consideration, as well as the power available and the number of parts to be produced.

Fig. 27 is a drawing showing the front view of a lower forging die and sections. This die is for a differential spider, and the piece part is shown at the lower left-hand corner of the drawing. As will be seen from the figure, one half of the piece part is laid out in the lower die section and the other half of the impression is contained in the upper die. Therefore, when the hot metal that is to be forged is placed between these dies, and the drop-forge hammer is operated, the constant blows form this metal into the shape desired. The plan view of the lower die is shown by Fig. 28. It will be noted in this drawing that the clearance is milled around the contour of the piece part to provide space for the flash that will be caused by the action of the upper and lower die sec-

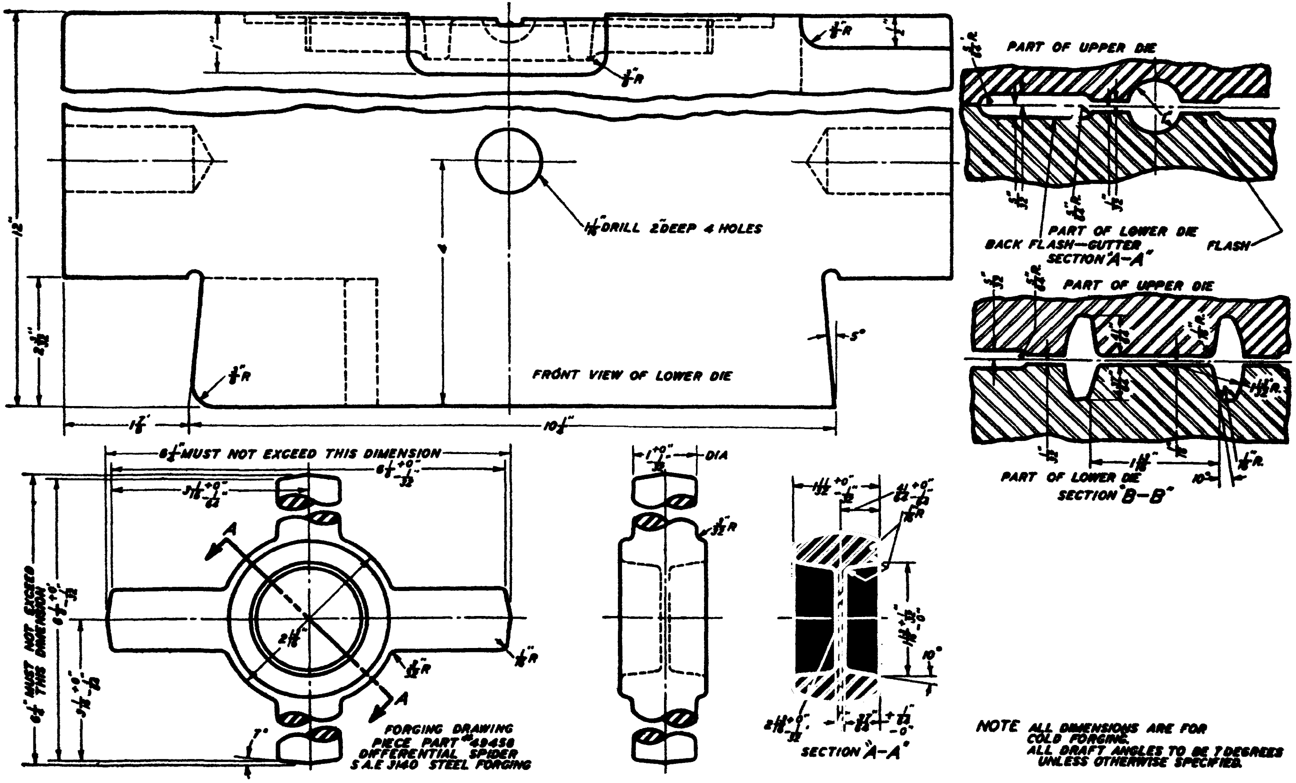


Fig 27. Front View of Lower Die and Sections Forging Drawing of Differential Spider

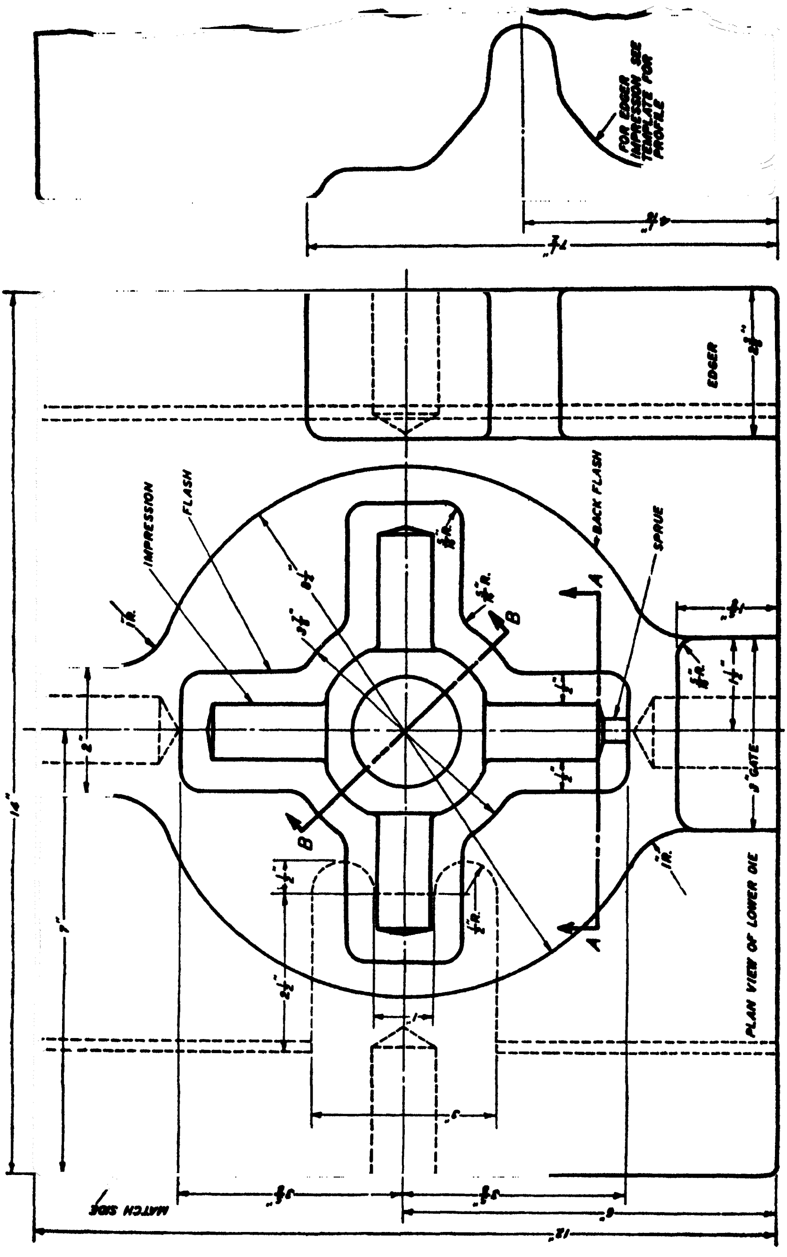


Fig. 28. Plan View of Lower Die and Edger Impression, Side View

tions on the forging metal. This is a comparatively simple drop-forging die, but the principles used in its design are applicable to most other types of drop-forging dies, whether the piece parts are to be steel forgings, brass, bronze or copper forgings.

On forging dies for certain types of brass and copper forgings the finish in the die itself is smoother, due to the fact that appearance in some instances is of great importance. Naturally, the finish that is put into the die will produce the finish of the piece part.

Bulldozer Dies. This type of die is designed to be used in presses that are of the horizontal type and have a crank similar to a power punch press. They are frequently used for forming structural shapes and also various types of flat work. The design of dies for this type of machine is comparatively simple in comparison with other types of dies that are generally used in power punch presses.

In the lower part of Fig. 29 is a piece part that is formed of steel $\frac{3}{16}''$ thick. The part has two bends in it, and to produce a part of this kind a bulldozer die (shown in the upper portion of this drawing) is designed. This type of die consists of two parts: the moving die, detail *1*; the stationary die, detail *2*. Most of the parts that are formed in bulldozer dies are heated in a furnace, the amount of heat depending on the work to be done; ordinarily, the stock is heated to approximately a cherry red. The stop pins and gages are provided in the machine so that the dies will form or bend the piece in the required manner. In some instances this type of die has cams that operate movable sections on the outer end of the bed of the bulldozer press so that, after certain forms have been accomplished in the central portion of a piece part, the ends can be bent by means of cams operating the forming sections at the outer edges of the bulldozer die.

Die-Casting Dies. The use of die castings for piece parts has been constantly increasing in the metalworking industry during the past few years. Due to the improvements in methods of alloying metals such as lead, zinc, copper, etc., numerous parts that were considered too fragile for die-casting dies are now being made successfully. Some of these piece parts are comparable in tensile strength to that of steel. The outstanding advantage of die casting for piece parts is that very little machining is required after these

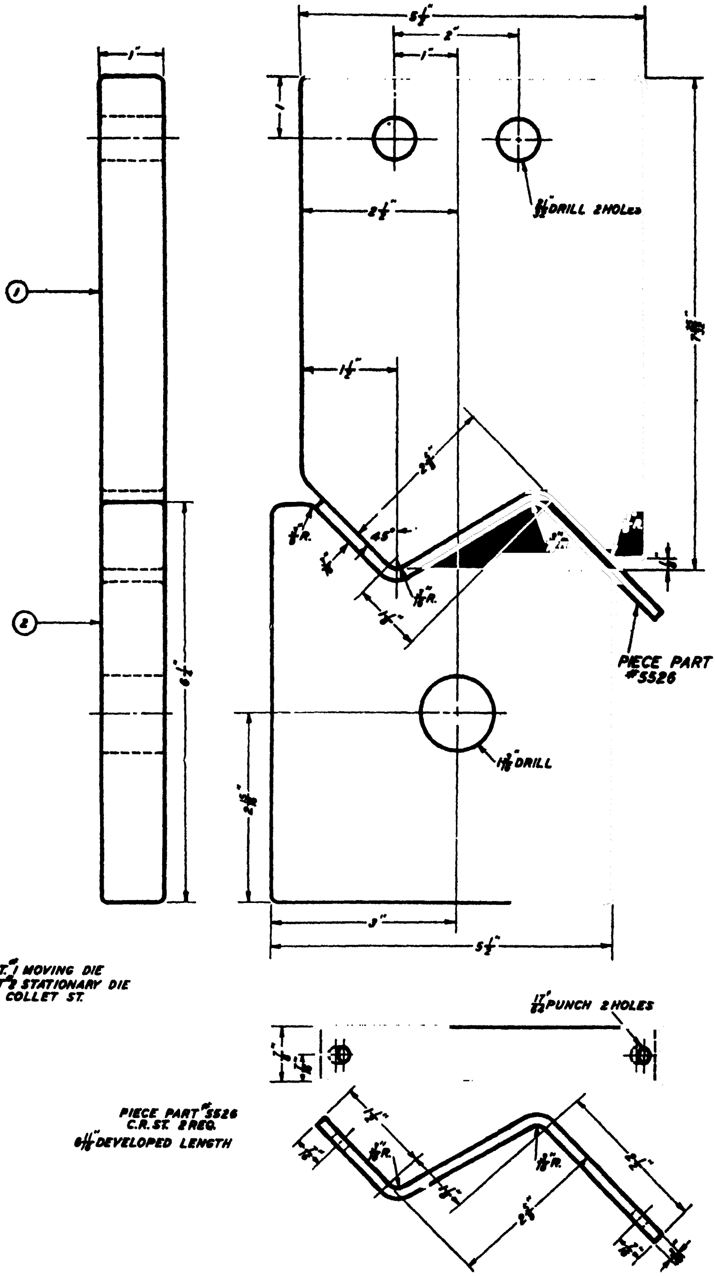


Fig. 29. Bulldozer Dies for Making Double Bend in Piece Part No. 5526

parts have been produced in the die-casting die. In numerous instances inserts consisting of bushings and studs can be produced in screw machines very inexpensively and then placed in these dies and when the die-casting metal is poured into the die these parts become almost integral with the part itself. The automotive industry has been largely responsible for the use of die-casting dies.

The designing of die-casting dies has become a specialty, and the average tool designer is not usually called upon to design them. However, it is well for him to have a fundamental knowledge of this practice. The die-casting die is somewhat similar in principle to permanent molds. These of course are metal molds that are used in foundry practice to produce cast-iron parts that require a hard outer surface. Die-casting machines (that is, the machines in which the die-casting dies are used) put out by different manufacturers have different characteristics; therefore, it is necessary for the tool designer to know what type of machine is going to be used in conjunction with the dies he is called upon to design.

The principle of design for die-casting dies is that there are two parts to these dies also, the upper and the lower. The dies are designed so that the upper part is one half of the impression of the piece part and the lower die is the other half; this is similar to drop forging dies. In addition, channels must be provided so that the metal will flow to the parts required. Risers must be put into the die so that the metal will flow to the required height to completely fill the impression.

Fig. 30 is a working drawing of the upper half of a waffle iron griddle. Waffle irons are in common use in the majority of homes, and many of us have used them without giving much thought as to how they are made. This upper half of the griddle iron is made of aluminum die-casting alloy. Fig. 31 shows the plan view of the die-casting die for the upper half of a waffle iron griddle. These dies are designed to be made out of an alloy steel and it will be noted that the form of the upper part of the griddle has been reproduced in steel in the center of this die. Due to the fact that the die-cast metal is poured at a high melting point, these dies get very hot and would soon distort unless there were some way of cooling them; therefore, water is allowed to flow through the dies to keep the temperature down. Holes are drilled and the ends of the die block itself are tapped for pipe fittings so that water can be constantly circulated through the lower portion of the die-casting die. Knockout pins must be provided so that the piece part, when allowed to cool, will not stick in the die.

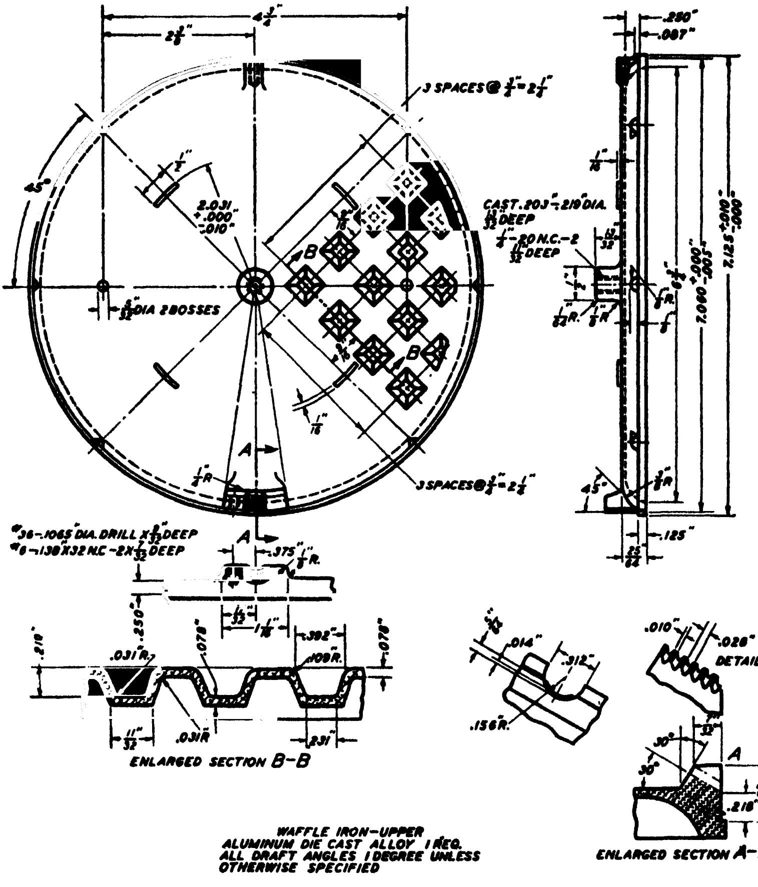


Fig. 30. Working Drawing of Upper Half of Waffle-Iron Griddle

Fig. 32 is a front view showing the right side of the die-casting die for the upper half of a waffle iron griddle. You will note it is necessary to section this drawing in order to convey the correct impression to the tool maker who will make this die.

Die-casting dies are frequently designed for several impressions at one time. The die-casting die that has been described here is used for producing two parts simultaneously, or, as it is termed.

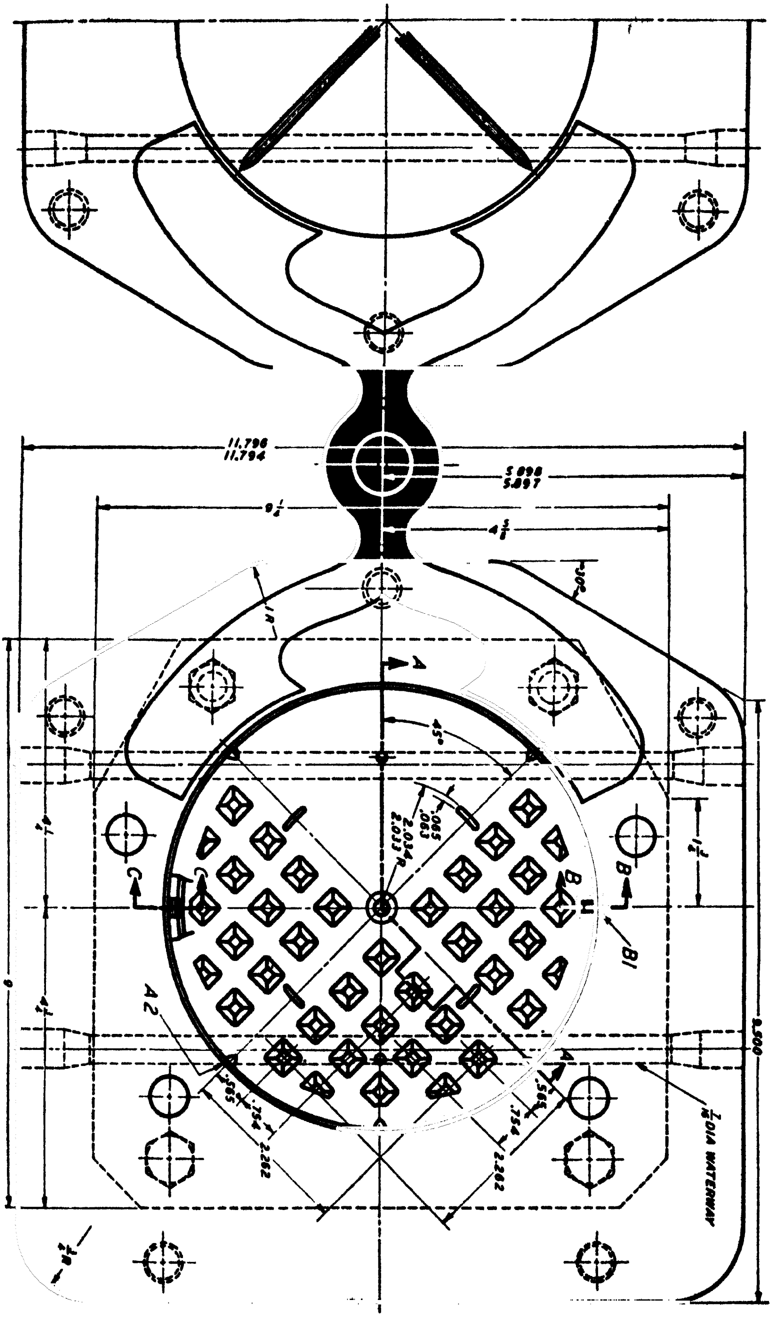


Fig. 31. Plan View of Die-Casting Die for Upper Half of Waffle-Iron Griddle

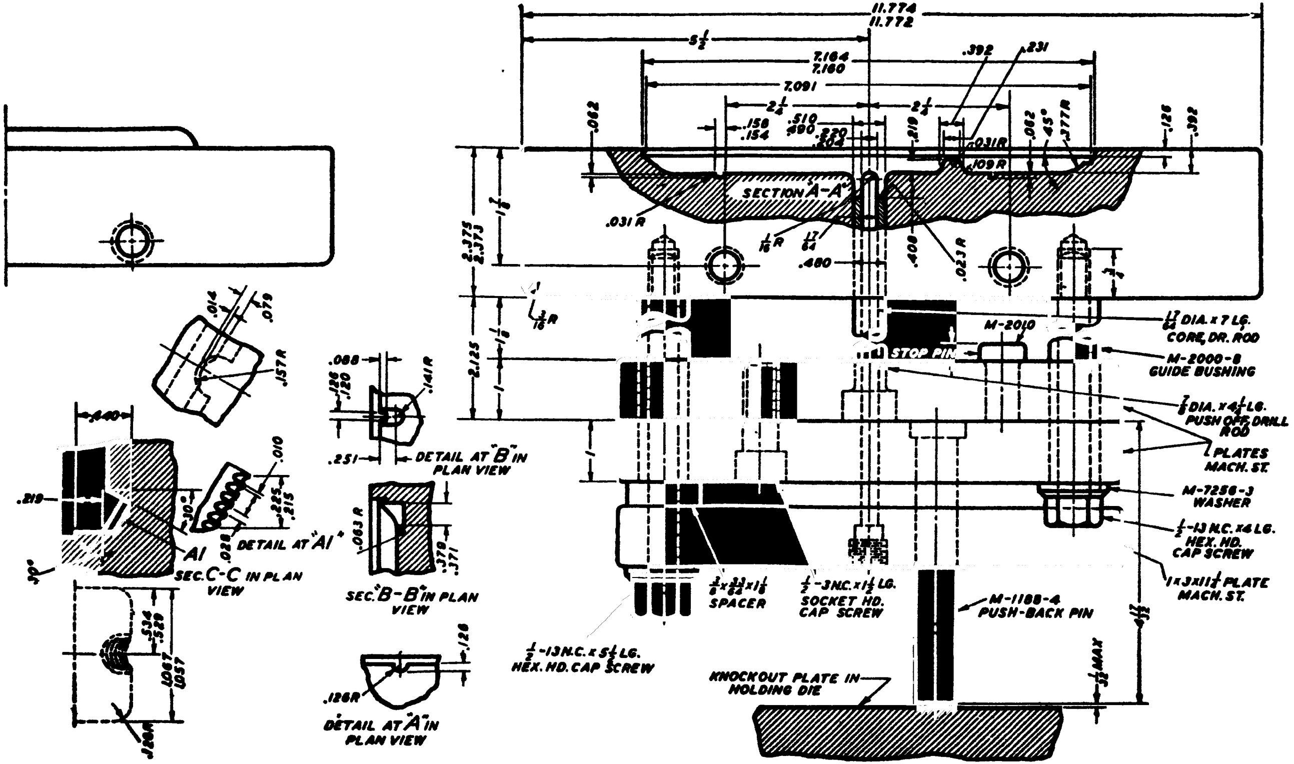
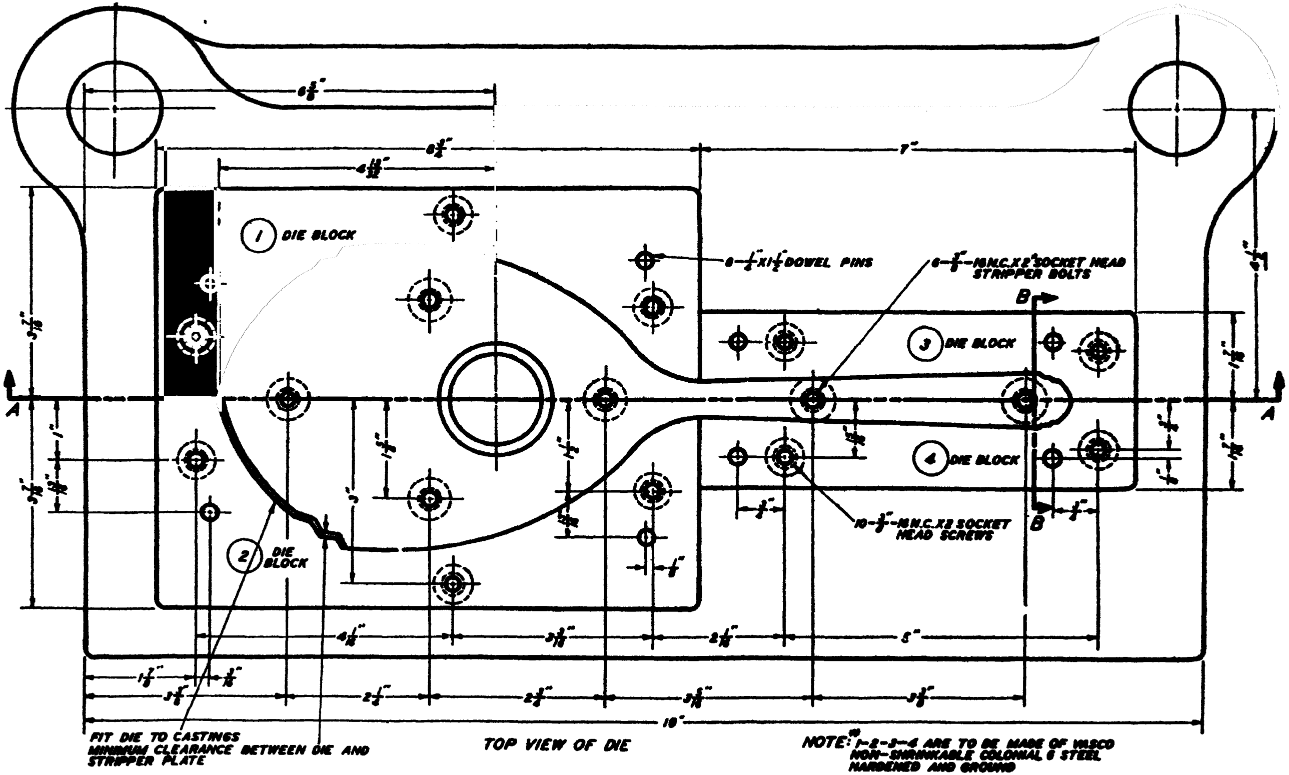


Fig. 32. Front View (Right) of Die-Casting Die for Upper Half of Waffle-Iron Griddle



FIT DIE TO CASTINGS MINIMUM CLEARANCE BETWEEN DIE AND STRIPPER PLATE

TOP VIEW OF DIE

NOTE: 1-2-3-4 ARE TO BE MADE OF VASCO NON-SHRINKABLE COLONIAL 6 STEEL HARDENED AND GROUND

Fig. 33. Plan View of Die-Casting Trimming Die for Trimming Hand Mirror

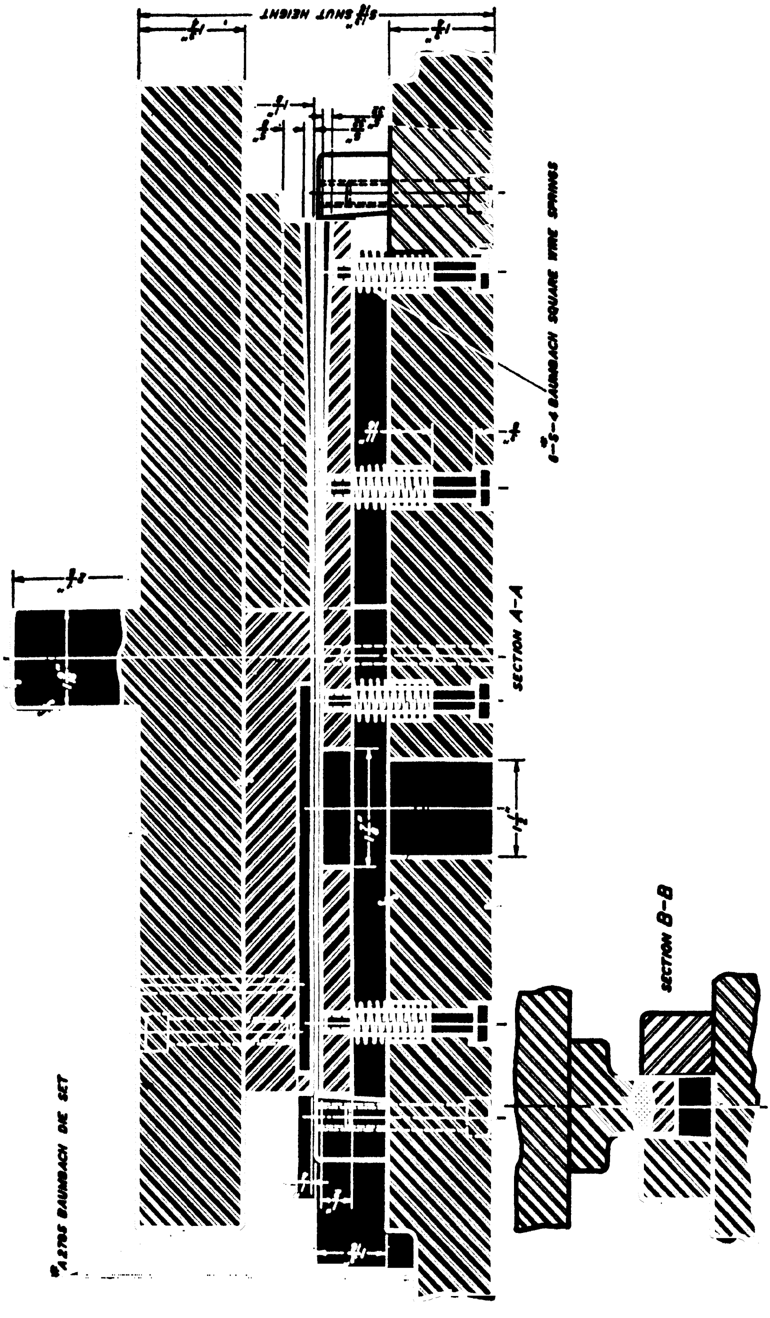
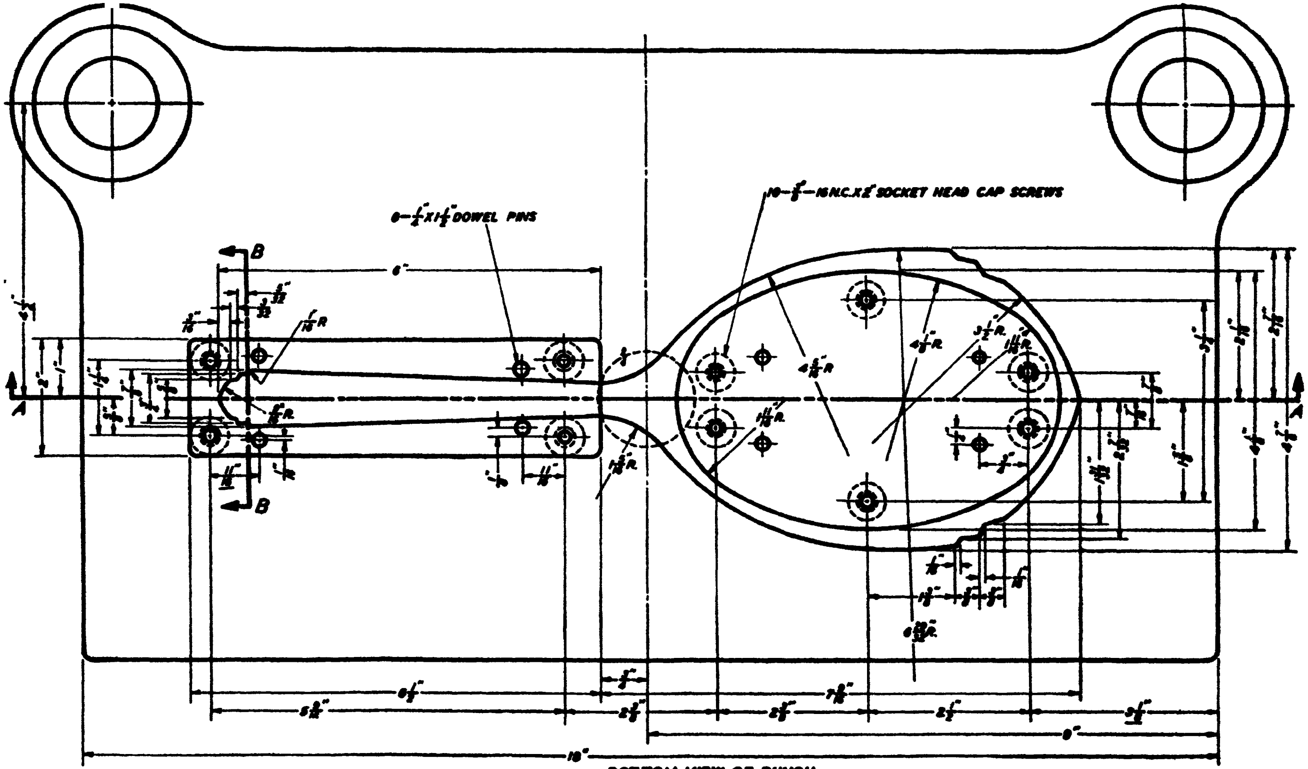


Fig. 34. Front Sectional View of Die-Casting Trimming Die for Trimming Mirror Handle



BOTTOM VIEW OF PUNCH

Fig. 35. Bottom View of Die-Casting Trimming Die Punch

two impressions. The molten metal is fed into the die by means of pressure and through the central section. The making of die-casting parts is in reality a division of foundry practice, but these die-casting dies or metal molds are used instead of sand.

Die-Casting Trimming Dies. On certain types of parts that are produced by means of die-casting dies, it is necessary to provide trimming dies to remove the flash that is caused in the molding process. This flash, or excess metal, is caused by the fact that it is impossible to have the upper and lower halves of a die-casting die meet closely, due to the difficulties inherent in the piece part design. The flash must be removed from these piece parts; therefore, trimming dies are designed.

Fig. 33 is a plan view of a die-casting trimming die used for trimming a hand mirror. This mirror is made out of a die casting and then plated. The die sections of this die are made to suit the contours of the piece part. It is mounted in a standard two-leader-pin die set by means of dowel pins and socket head screws. There is a shutter mounted in the die opening so that the piece part will rest on it. This shutter is supported by means of bolts with springs on them. The punch section of the die is merely a general outline of the piece part to support it properly. In action, the piece part is loaded into the die and the press is operated, pushing the piece part down into the die sections that trim off the flash wherever it may occur. This saves considerable hand labor that would be necessary if the die were not designed, as it would be necessary to remove this flash by means of filing or grinding.

The sectional view of this die is shown by Fig. 34. In this drawing, a section through the center of the trimming die is shown. Fig. 35 is a bottom view of the punch section of this die-casting trimming die.

Some types of trimming dies are very simple. A piece of tool steel is designed to be made to follow the contour of the piece part and mounted in the ram of the press or in a punch holder to push the piece part through the die opening. This is sufficient to trim off the flash in the die-casting piece part.

QUIZ QUESTIONS

1. Name some of the advantages stampings have over castings.

2. What constitutes the overall height of a die? How does this affect the height of the punch press?

3. In designing dies, why is it advisable to work from the center of the piece part outward?

4. How great a radius should be allowed for a right-angle bend in a forming die?

5. What is the formula for calculating the size of the press required to handle a certain job?

6. In designing a die, what views should be laid out so that the tool maker will have a clear picture of the construction of the die?

7. Explain some of the methods used in providing proper stripping facilities for a die.

8. In piercing dies, what is the rule for determining the clearance between the punch and the die section?

9. Why is only a small clearance allowed in the button die shown in Detail 25, Fig. 12? What difficulty sometimes arises from allowing a very small amount of clearance between the punch and the die?

10. In the forming die shown in Fig. 15, why is the punch designed to be made at an 85° angle instead of the 90° angle shown by the piece part?

11. What is the special function of compound blanking and piercing dies?

12. What is the usual percentage of carbon in the steels used for making drop-forging dies?

13. Why is it essential that proper draft be provided when making piece parts in drop-forging dies?

14. On what type of work are bulldozer dies generally used?

15. What are some of the advantages in using die castings for piece parts?

16. What is the usual method of removing the flash caused in the process of molding certain types of parts by means of die-casting dies?

QUICK AND ACCURATE SETUP OF ANGLE PLATES IN BORING ANGULAR HOLES

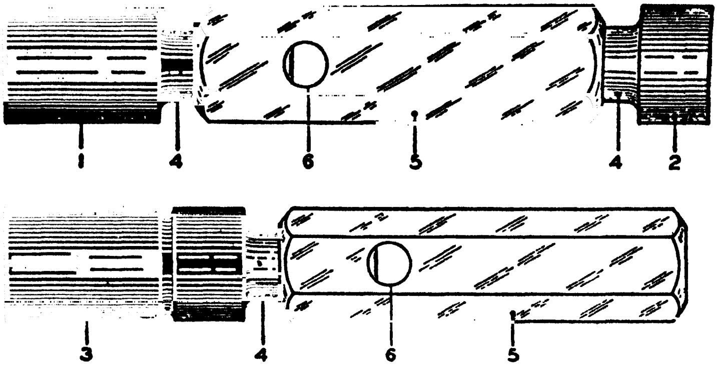
Courtesy of The Cleveland Universal Jig Co., Cleveland, Ohio

GAGES

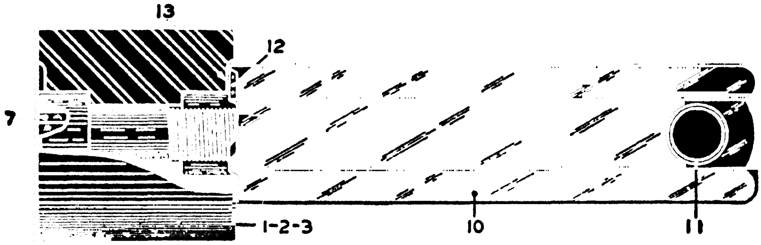
In modern metal manufacturing, gages are very important due to the fact that it would be almost impossible to produce parts that are interchangeable unless some method of gaging were provided. In this section the attention of the reader should be focused on the drawings, as they give many fundamental hints regarding the designed gages. Gages are used extensively in all the high-production industries because they determine the accuracy of piece parts from operation to operation. Without the use of gages, the cost of manufacturing parts on an interchangeable basis would be exorbitant. There are three classes of gages in most of the high-production plants, as follows: the working gage which is used by the operator on the machine for the particular operation he is doing; the inspection gage which is used by the inspectors to check the work produced at the machine; and the master or reference gages which are used to check the inspection gages.

The materials from which gages are made have been improved during the past few years. Formerly most of the gages were made out of cold-rolled or machine steel, carburized, hardened, and then ground. Today gages are made from a wide variety of materials. Certain types of gages have Stellite welded on them at the gaging points to prevent excessive wear, particularly when they are to be used in conjunction with grinding operations. The use of chrome-plated gages has been increasing due to the fact that chrome is very hard and resists abrasion better than most types of steel. On certain types of indicating gages, Tungsten Carbide tips are used, and in some instances these types are equipped with diamond points to eliminate wear.

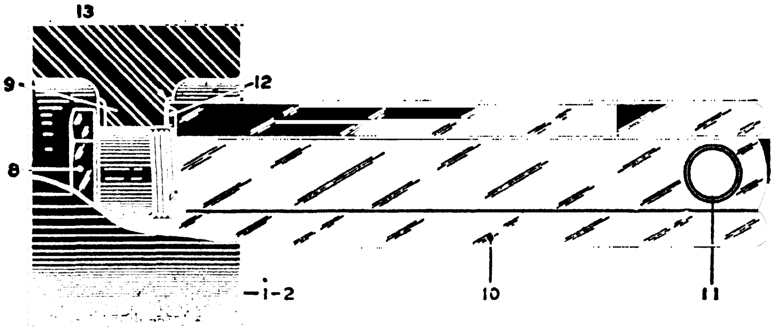
The tool designer in designing gages should always specify the limits to which the gage must be made; in other words, flat dimensions should not be used. In the event that a plug gage is to be designed to fit a hole that would be 2.5625", there should be a tolerance following this figure; that is, it should read plus or minus .0002". This is an indication to the shop that the dimension given on the gage must be kept within those limits.



Range: Above 0.059 to and including 1.510 inches; optional above 1.510 to and including 2.510 inches.



Range: Above 1.510 to and including 2.510 inches.



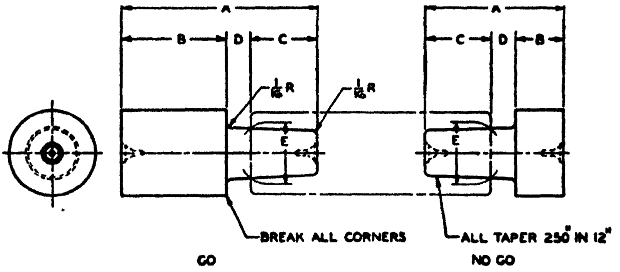
Range: Above 2.510 to and including 8.010 inches

Details of Construction

1. "Go" gaging member
2. "No go" gaging member
3. Progressive gaging member
4. Shank
5. Taper lock handle
6. Drift hole (or slot)
7. Socket head screw
8. Hexagon head screw
9. Web
10. Handle for reversible gage
11. Cross-pin hole
12. Locking prong
13. Locking groove

Fig 1 American Gage Design Standard Plain Cylindrical Plug Gages

Plain Cylindrical Plug Gaging Members, Taper Lock Design



Handle Size No.	Range in Diameters		General Dimensions, Inches											
			Go						No Go					
	Above	To and Including	A	B	C	D	E		A	B	C	D	E	
							Min.	Max.					Min.	Max.
1. .	.240	.365	1¾	¾	¾	¼	.239	.240	1⁵⁄₁₆	⁵⁄₁₆	¾	¼	.239	.240
2.	.365	.510	2	1	¾	¼	.309	.310	1⅜	⅜	¾	¼	.309	.310
3.	.510	.825	2¼	1¼	¾	¼	.408	.410	1½	½	¾	¼	.408	.410
4.	.825	1.135	2⁹⁄₁₆	1⅜	⅞	⁵⁄₁₆	.608	.610	1¹³⁄₁₆	⅝	⅞	⁵⁄₁₆	.608	.610
5.	1.135	1.510	2⅞	1½	1	⅜	.808	.810	2⅛	¾	1	⅜	.808	.810

Handle Size No.	General Dimensions, Inches							
	Progressive							
	A	B	C	D	E		F	G
					Min.	Max.		
1	2³⁄₁₆	1³⁄₁₆	¾	¼	.239	.240	⁵⁄₁₆	¾
2	2½	1½	¾	¼	.309	.310	⅜	1
3	2⅞	1⅞	¾	¼	.408	.410	½	1¼
4	3⁵⁄₁₆	2⅛	⅞	⁵⁄₁₆	.608	.610	⅝	1⅜
5	3¾	2⅜	1	⅜	.808	.810	¾	1½

The range in diameters is the same as given above for *Go* gages.

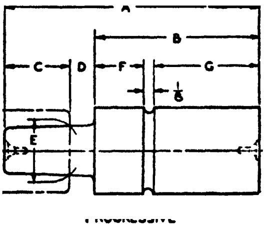
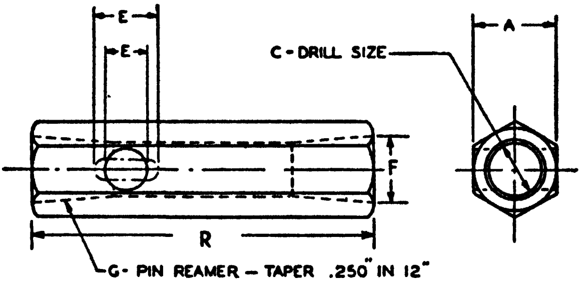


Fig. 2A

Plug Gages. These are the gages most frequently used. Fig. 1 shows designs of single-end and double-end plug gages that have been adopted as standard by the American Gage Manufacturers Association. Figs. 2A and 2B are a chart of general dimensions of the various components that go to make up the single- and double-end plug gages. By referring to these charts the tool designer can select the right design for any special plug gage that he may be required to produce. These gages are furnished by commercial

Handles for Plain Cylindrical Plug Gages, Taper Lock Design



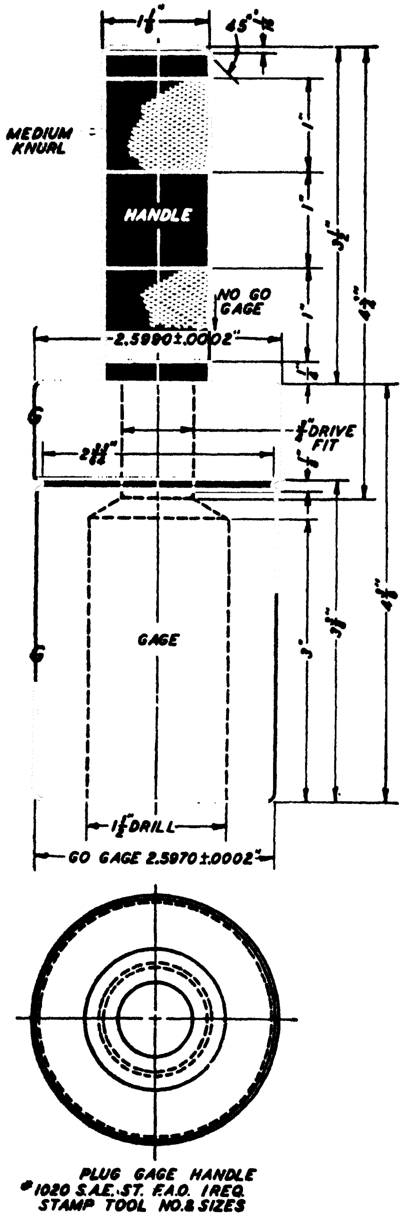
Handle Size No.	Decimal Range, Plain and Thread Plug Diameters		General Dimensions, Inches								
	Above—	To and Including—	A	B	C	D	E	F		G No.	L
								Min.	Max.		
1	.240	.365	3/8	2 3/4	7/32	23/32	1/8 by 1/2 Diameter	.239	.240	4	1/16
2	.365	.510	1/2	3	L (0 290)	25/32	15/64	.309	.310	6	1/16
3	.510	.825	11/16	3 1/4	25/64	27/32	11/32	.409	.410	7	3/32
4	.825	1.135	7/8	3 5/8	37/64	63/64	3/8	.609	.610	10	3/32
5	1.135	1.510	1 1/8	4	25/32	1 1/8	7/16	.809	.810	11	1/8

Fig. 2B

manufacturers in various standard dimensions, but usually the specials are designed to suit the needs of the particular job for which they are to be used.

Plug gages are used for determining the sizes of holes in the piece parts. They consist of a *Go* and *No Go*. The *Go* gage is supposed to enter the hole and the *No Go* gage should not enter the hole; if the *No Go* gage enters the hole, the hole in the piece part is oversize.

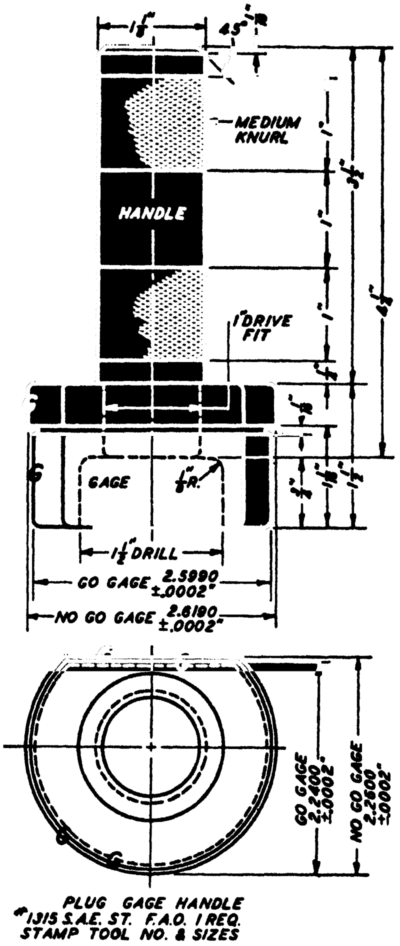
Special Plug Gages. In designing special plug gages, particularly in sizes that are fairly large, weight is a considerable factor and heavy gages are sometimes ruined because the operator becomes tired in handling them and drops them, which causes damage to the gage. Fig. 3 is a design of a *Go* and *No Go* plug gage. This gage is made in two sections. The gage portion has been lightened by drilling a 1½" hole in it, and a separate handle which is made of soft steel is fitted to the gage portion by means of a drive fit. This design is very inexpensive as it is necessary to harden and grind only the gage portion.



PLUG GAGE HANDLE
#1020 S.A.E. ST. F.A.O. 1 REQ.
STAMP TOOL NO. & SIZES

PLUG GAGE
#1020 S.A.E. ST. F.A.O. 1 REQ.
HEAT TREAT 1020 A ROCKWELL "C" 60 MIN.
CASE DEPTH .060"
GRIND & LAP

Fig. 3. Large "No Go" and "Go" Plug Gages for Finished Bore of Differential Bevel Gear and Spur Pinion



PLUG GAGE HANDLE
#1315 S.A.E. ST. F.A.O. 1 REQ.
STAMP TOOL NO. & SIZES

PLUG GAGE
#3120 S.A.E. ST. F.A.O. 1 REQ.
HEAT TREAT 3120 A. ROCKWELL
"C" 60-63 CASE DEPTH .050"-.060"
GRIND & LAP

Fig. 4. Large "No Go" and "Go" Plug Gages for Differential Thrust Washer

Fig. 4 is a design of a special plug gage made somewhat similar to that described for Fig. 3, but it is made to gage a piece that is considerably thinner; therefore the gage can be made shorter. In addition, this gage has a flat on one side in order to fit the inside of the piece part, which is a thrust washer produced in a die by means of a punch press.

Flat Plug Gages. These are inexpensive gages designed for use on holes of large diameter. See Fig. 5. Although not so accurate as round plug gages, they work out very well for use by operators at the machine. This gage, as it will be noted, is made out of flat steel ½″ thick and is centered on each end, then turned in the lathe, then ground to the finished dimensions.

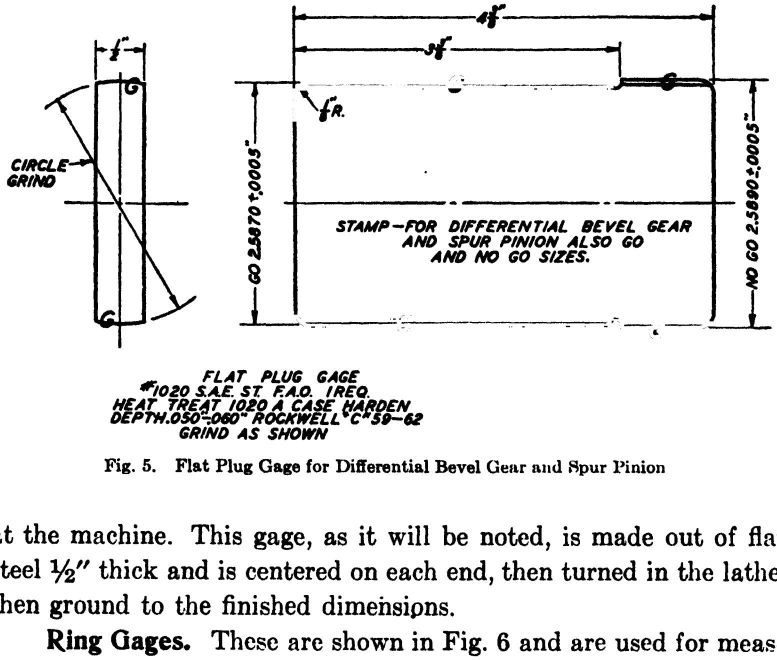
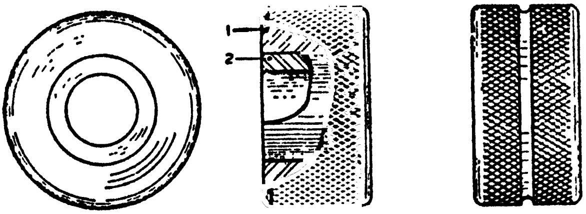
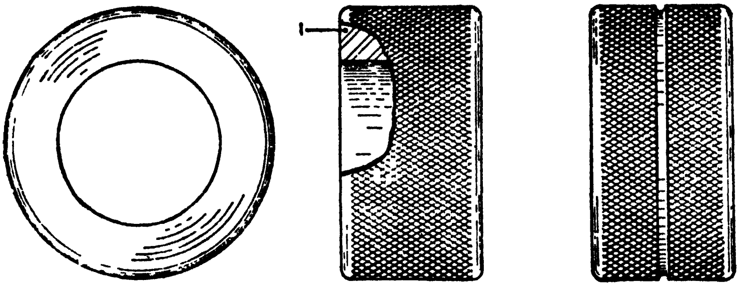


Fig. 5. Flat Plug Gage for Differential Bevel Gear and Spur Pinion

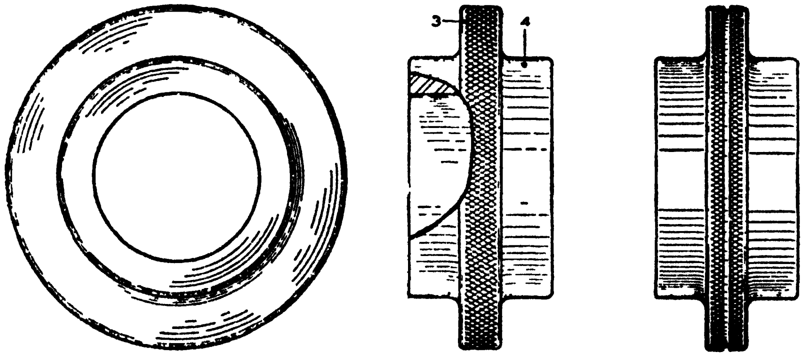
Ring Gages. These are shown in Fig. 6 and are used for measuring the diameters of shafts and other round parts. The design of this type of gage has also been standardized by the American Gage Manufacturers Association. The *Go* ring gage is knurled on the outside diameter, and on certain sizes a hardened and ground tool-steel bushing is inserted. The *No Go* gage is practically identical except that a groove is turned on the outside diameter to distinguish the *No Go* from the *Go* gage. On ring gages of large diameter considerable metal is removed from the outside diameter to lighten the gage. A chart showing the dimensions of this type of gage is shown by Figs. 7A and 7B. The designer can use this in designing special ring gages that may be required.



Range: Above 0.059 to and including 0.510 Inch



Range: Above 0.510 to and including 1.510 Inches

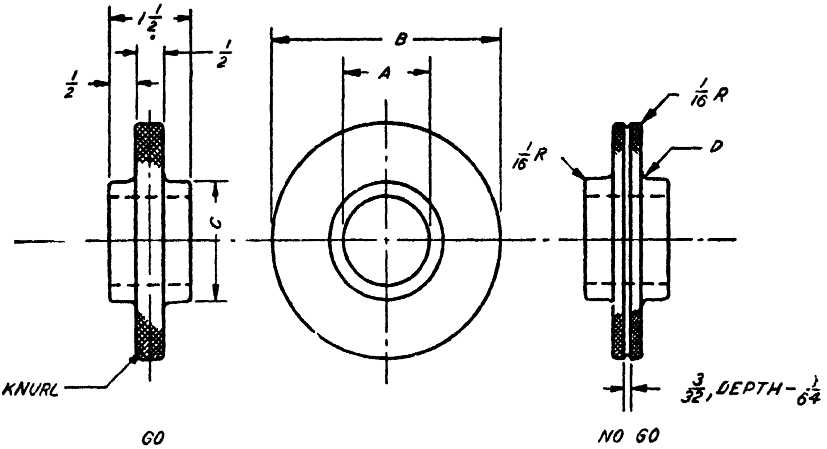


Range: Above 1.510 to and including 5.510 Inches

Fig. 6. American Gage Design Standard Plain Ring Gages, Details of Construction. *1* Body; *2*, Bushing; *3*, Flange; *4*, Hub

Thread Gages. The use of thread gages is also increasing due to the fact that ground thread taps are in common use in the average metalworking plant today; therefore closer fits on threads are easily obtainable. These thread gages are made standard by many commercial companies, and the tool designer can obtain in-

Plain Ring Gages, Range Above 1.510 to and Including 4.510 Inches



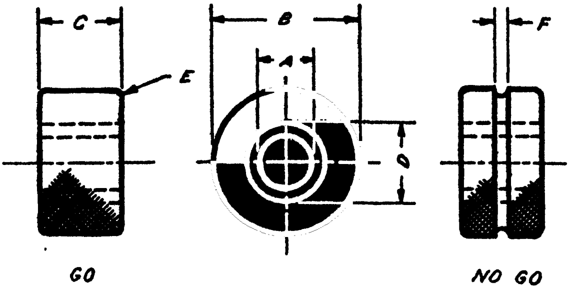
Ring Size No.	A Range		B Outside Diameter	C Hub Diameter	D Radius	Ring Size No	A Range		B Outside Diameter	C Hub Diameter	D Radius
	Above	To and Including –					Above –	To and Including –			
6	1.510	2.010	4½	A + ⅞	⅛	9	3.010	3.510	6	A + 1	3/16
7	2.010	2.510	4⅝	A + ⅞	⅛	10	3.510	4.010	6⅞	A + 1⅛	¼
8	2.510	3.010	5½	A + 1	3/16	11	4.010	4.510	7⅜	A + 1⅛	¼

Fig. 7A

formation from the manufacturer's catalog. Fig. 8 shows ring and plug thread gages. The ring gage is split so that it can be adjusted to fit the plug. The plug is used for checking the tapped hole, and the ring thread gage is used for checking the threaded part that fits into the tapped hole. These gages are also designed with *Go* and *No Go* limits.

Snap Gages. For checking the dimensions from one shoulder to another on a shaft, snap gages similar to Fig. 9 are designed. This type of gage is made out of flat stock, and grinding clearance is drilled in the bottom of the four gaging points so that the grinding wheel will not hit the center portion of the gage They are stamped *Go* and *No Go* to the required dimensions, and note that instructions to lap the grinding surfaces have been put on this drawing. Gages to close tolerance should always have a notation that the gaging points should be lapped after grinding, as lapping

Plain Ring Gages, Range Above 0.059 to and Including 1.510 Inches



Ring Size No.	A Range		General Dimensions, Inches					
	Above—	To and Including—	B Outside Diameter	C Thickness	D Bushing Diameter	E Radius	F "No Go" Groove Width	Length of Bushing
00........	.059	.150	15/16	3/16	3/8	1/32	1/32	(*)
0........	.150	.240	15/16	3/8	7/16	1/32	1/16	(*)
1........	.240	.365	1 1/8	9/16	9/16	1/16	3/32	(*)
2........	.365	.510	1 3/8	3/4	3/4	1/16	3/32	(*)
3........	.510	.825	1 3/4	15/16	(†)	3/32	3/32	(†)
4........	.825	1.135	2 1/8	1 1/8	(†)	3/32	3/32	(†)
5........	1.135	1.510	2 1/2	1 5/16	(†)	3/32	3/32	(†)

*Bushings are 1/16 inch longer than ring thickness, but are ground flush after hole is finished.
†Sizes 3,4 and 5 are solid.

Fig. 7B

removes the rough surface caused by the action of the grinding wheel and gives the gage considerably more life.

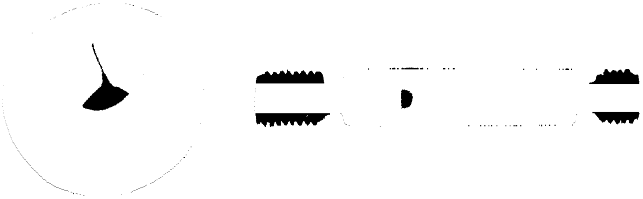


Fig. 8. Left, Thread Ring Gage; Right, Thread Plug Gage
Courtesy of The Taft-Peirce Manufacturing Co., Woonsocket, R. I.

Snap gages are also furnished as standard by numerous commercial gage companies. However, there are many instances where the commercial gage would not be suitable for a job; therefore, flat snap gages similar to Fig. 9 are designed to suit the needs of the individual job. For example, for checking the thickness of a

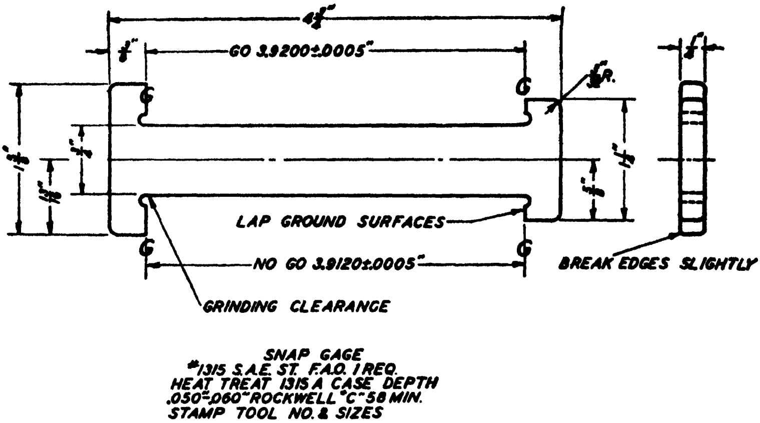


Fig. 9. Snap Gage for Gaging Length between Shoulders on a Differential Shaft

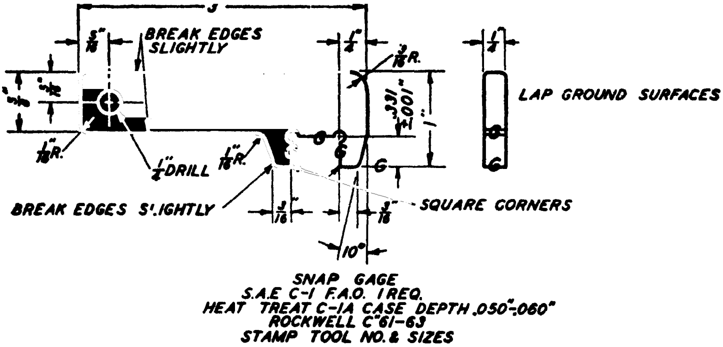


Fig. 10. Spur and Bevel Gear Tooth Snap Gage

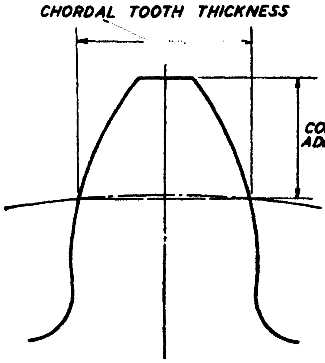


Fig. 11. Chordal Tooth Thickness and Corrected Addendum for Spur and Bevel Gear

gear tooth at the pitch line, Fig. 10 shows a design of a snap gage for measuring the thickness of a spur gear tooth. This gage is similar to the one previously described and it is used for measuring the gear tooth shown by Fig. 11.

For extra long work, particularly shafts, a snap gage similar to Fig. 12 is designed. Note that this gage is designed to be made of seamless steel tubing with inserted steel blocks that are welded in place. These blocks are made of an alloy steel, carburized, hardened, and ground to the dimensions required. This makes a gage of inexpensive design which is very satisfactory for the purpose for which it is used.

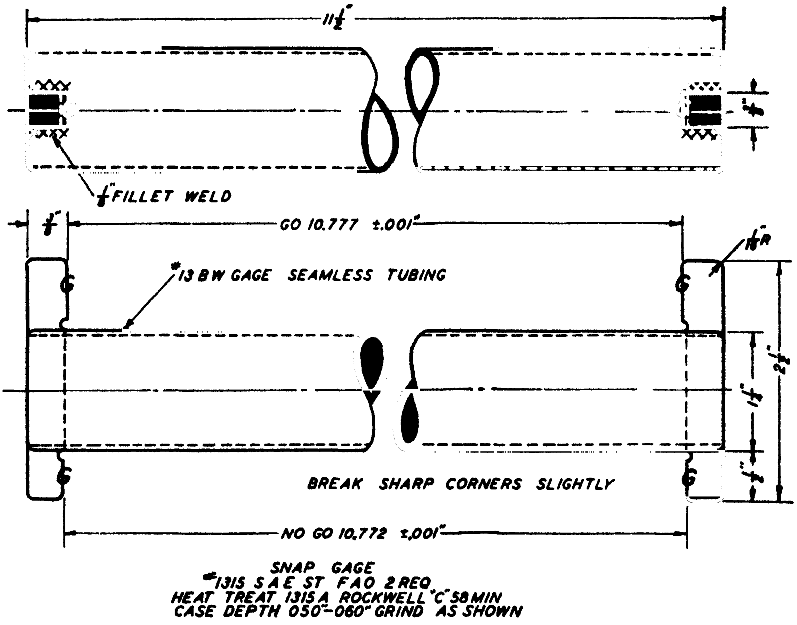

11½"
FILLET WELD
GO 10.777 ±.001"
1/16 R
#13 BW GAGE SEAMLESS TUBING
G
BREAK SHARP CORNERS SLIGHTLY
NO GO 10.772 ±.001"
SNAP GAGE
#1315 S A E ST F A O 2 REQ
HEAT TREAT 1315 A ROCKWELL "C" 58 MIN
CASE DEPTH 050"-060" GRIND AS SHOWN

Fig. 12. Snap Gage for Gaging Length of a Differential Shaft

Depth Gages. Depth gages, Fig. 13, are used for measuring the position of a collar or gear on a shaft, or a turned shoulder on a shaft. This gage is made out of flat stock and is usually an alloy steel that is carburized, hardened, and ground; although, for thin stock, commercial carbon steel ground flat stock is generally used. This gage has two steps, one for *Go* and one for *No Go.*

Gage Arbors. Hardened and ground taper gage arbors, Fig. 14, are designed to check the taper hole in a gage, also to put this arbor between centers and indicate the face of the gear to see that

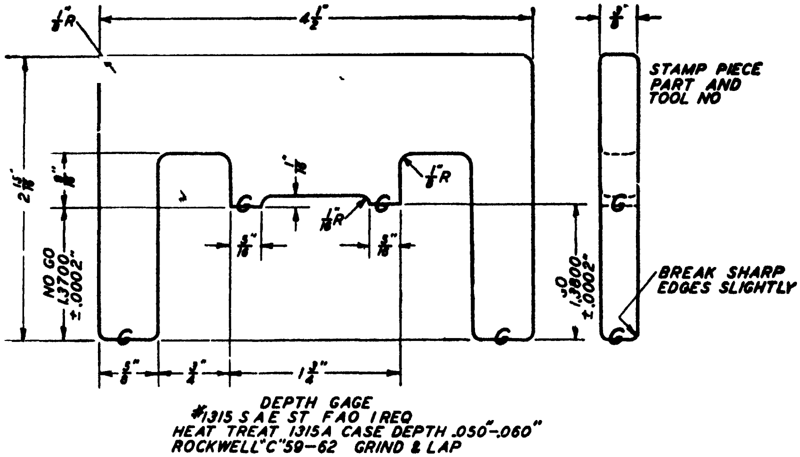

STAMP PIECE PART AND TOOL NO
BREAK SHARP EDGES SLIGHTLY
NO GO 1.3700" ±.0002"
GO 1.3800" ±.0002"
G
DEPTH GAGE
#1315 S A E ST F A O 1 REQ
HEAT TREAT 1315A CASE DEPTH .050"-.060"
ROCKWELL"C"59-62 GRIND & LAP

Fig 13 Depth Gage for Steering Worm Quill

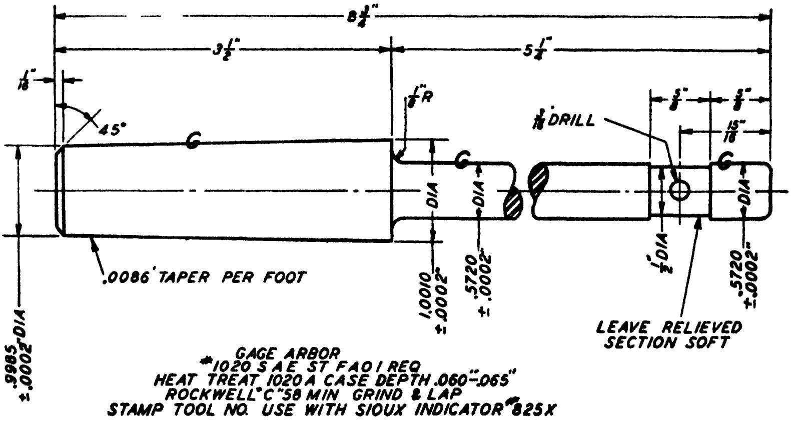
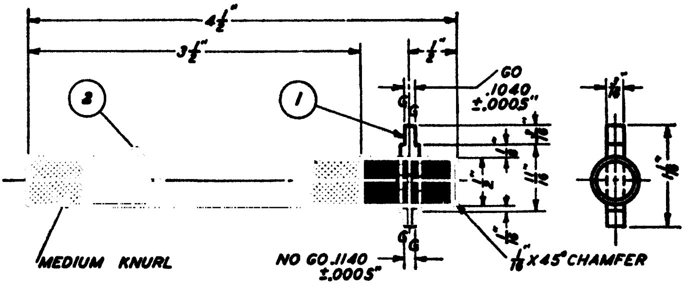

45°
G
DRILL
DIA
.0086' TAPER PER FOOT
1.0010 ±.0002"
.5720 ±.0002"
.9985 ±.0002" DIA
LEAVE RELIEVED SECTION SOFT
GAGE ARBOR
#1020 S A E ST F A O 1 REQ
HEAT TREAT 1020A CASE DEPTH .060"-.065"
ROCKWELL"C"58 MIN GRIND & LAP
STAMP TOOL NO. USE WITH SIOUX INDICATOR #825X

Fig 14 Arbor Used with Indicator for Gaging Squareness of Valve Guide Bore with Face of Cylinder Head

it is running true. This design is frequently employed by concerns that manufacture gears in quantities.

Width Gages. Width gages are for measuring the widths of grooves and slots in piece parts, Fig. 15. This design consists of a cold-rolled steel handle that is knurled, and a piece of drill rod that is hardened and ground and inserted at right angles to the handle. The *Go* and *No Go* dimensions of the slots are ground on this pin and it is a very efficient gage for the work for which it is designed.

Relation Gage. To check the relation of one or more holes and timing marks on a camshaft gear for an internal combustion engine, a relation gage is usually designed, Fig. 16. This gage is designed so it can be inserted in the central bore of the gear and is located in the three tapped holes in the gear by means of locator pins (*7*). The gaging points (*1*) and (*3*) are hardened and ground to eliminate wear. Numerous adaptations of this type of gage can be employed for checking the relations of a center bore in a piece part to holes that are drilled and tapped at certain distances from the central bore, such as the bolt circle of a coupling flange or dowel holes that have to be located properly in relation to similar holes in a mating part.

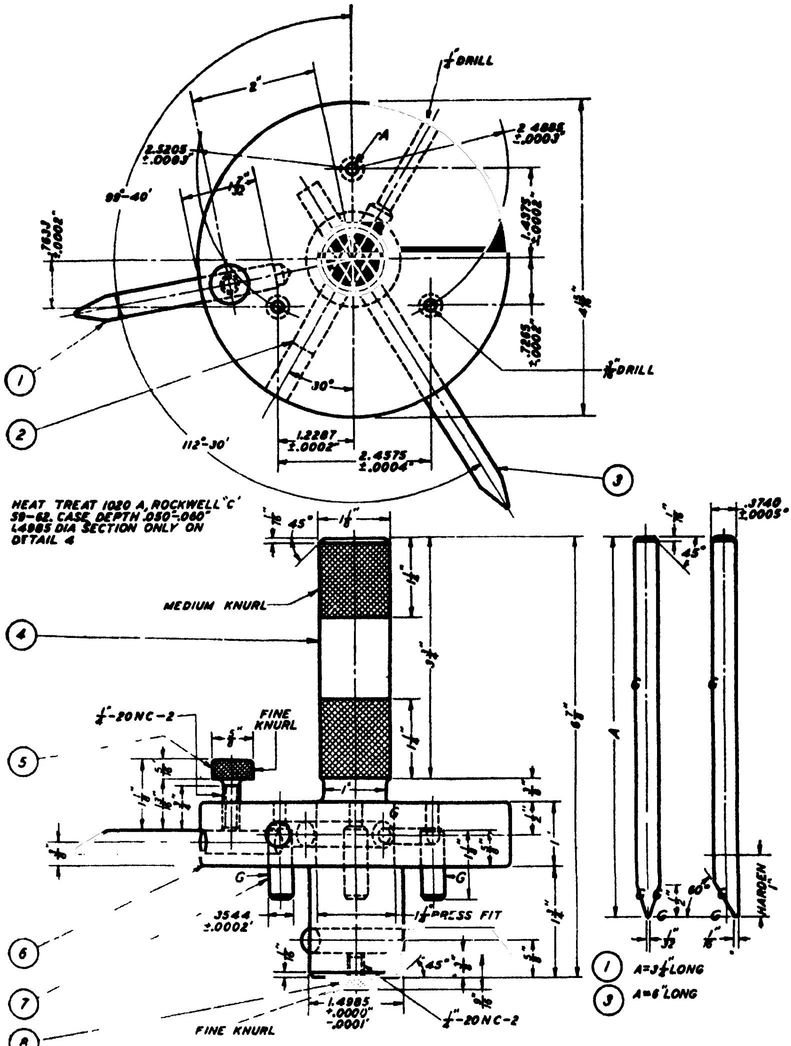


DET.#1 GAGE PIN
C.L. DRILL ROD F.A.O. 1 REQ.
HEAT TREAT C/A ROCKWELL "C" 59–62
CASE DEPTH .060" GRIND & LAP AS SHOWN

DET.#2 HANDLE
#1020 S.A.E. ST. 1 REQ.

Fig. 15. Width Gage for Gaging Groove on Inside Diameter of Sliding Gear

To check bevel gears, particularly for the face angle, also to check the concentricity of the outside diameter in relation to the center bore, a gage similar to Fig. 17 is designed. This is what is termed a built-up gage as it is made of several component parts. The details of this gage are shown by Fig. 18. This is a very efficient gage and the same design can be used for checking other piece parts having surfaces that must be indicated in relation to the center bore.



8	THUMBSCREW	7/16" DIA X 9/16" LG	C R ST		1
7	LOCATING PIN	3/8" DIA X 1 1/4" LG	DR ROD	HARD & GR	3
6	BODY	5 DIA X 1 LG	#1020 S AE		1
5	THUMBSCREW	5/8" DIA X 1 1/4" LG	C R ST		1
4	LOCATING PLUG	1 5/8" DIA X 7" LG	#1020 S.A.E.	HARD. & GR	1
3	LONG POINTER	3/8" DIA X 6 1/16" LG	DR ROD	HARD. & GR	1
2	DOWEL PIN	3/8" DIA X 2 1/2" LG	ST'D.		1
1	SHORT POINTER	3/8" DIA X 3 5/16" LG	DR ROD	HARD. & GR	1
DET	DESCRIPTION	ROUGH STK. SIZE	MAT'L.	HEAT TREAT	REQ

Fig 16. Gage to Check Relationship of Three Tapped Holes and Timing Marks on a Camshaft Gear

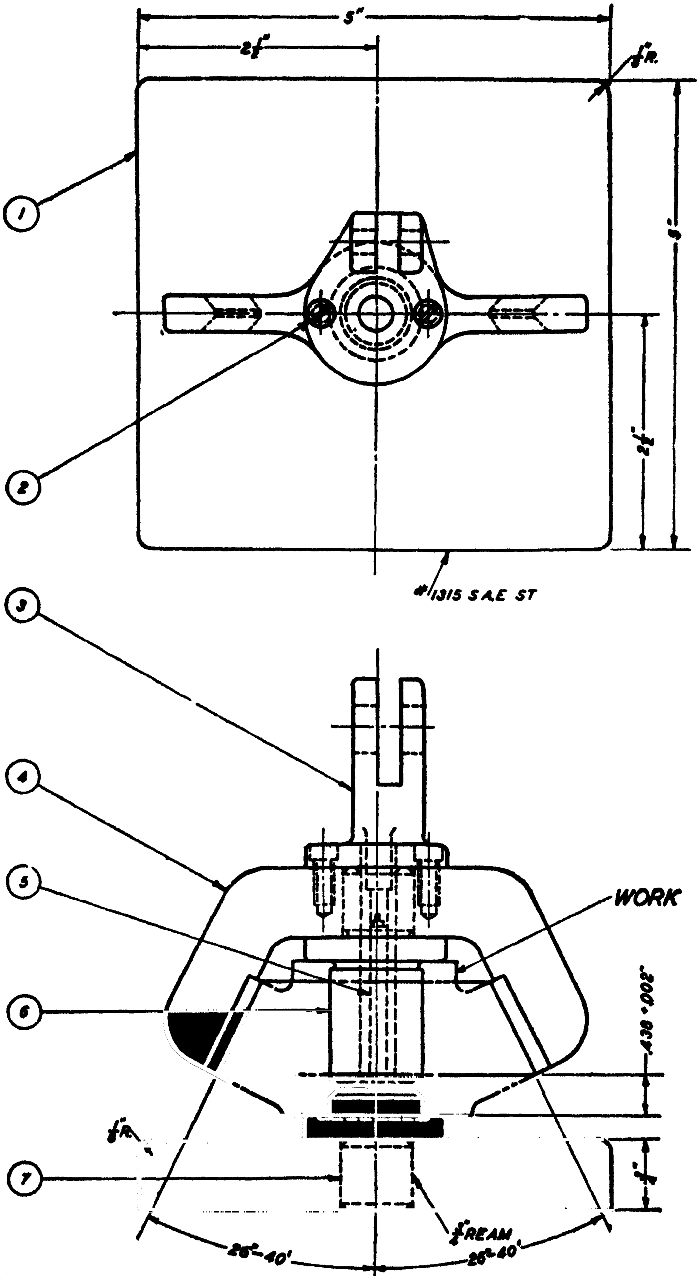


Fig. 17. Gage for Face Angle and Distance from Outside Diameter to Back of Hub on Bevel Gear

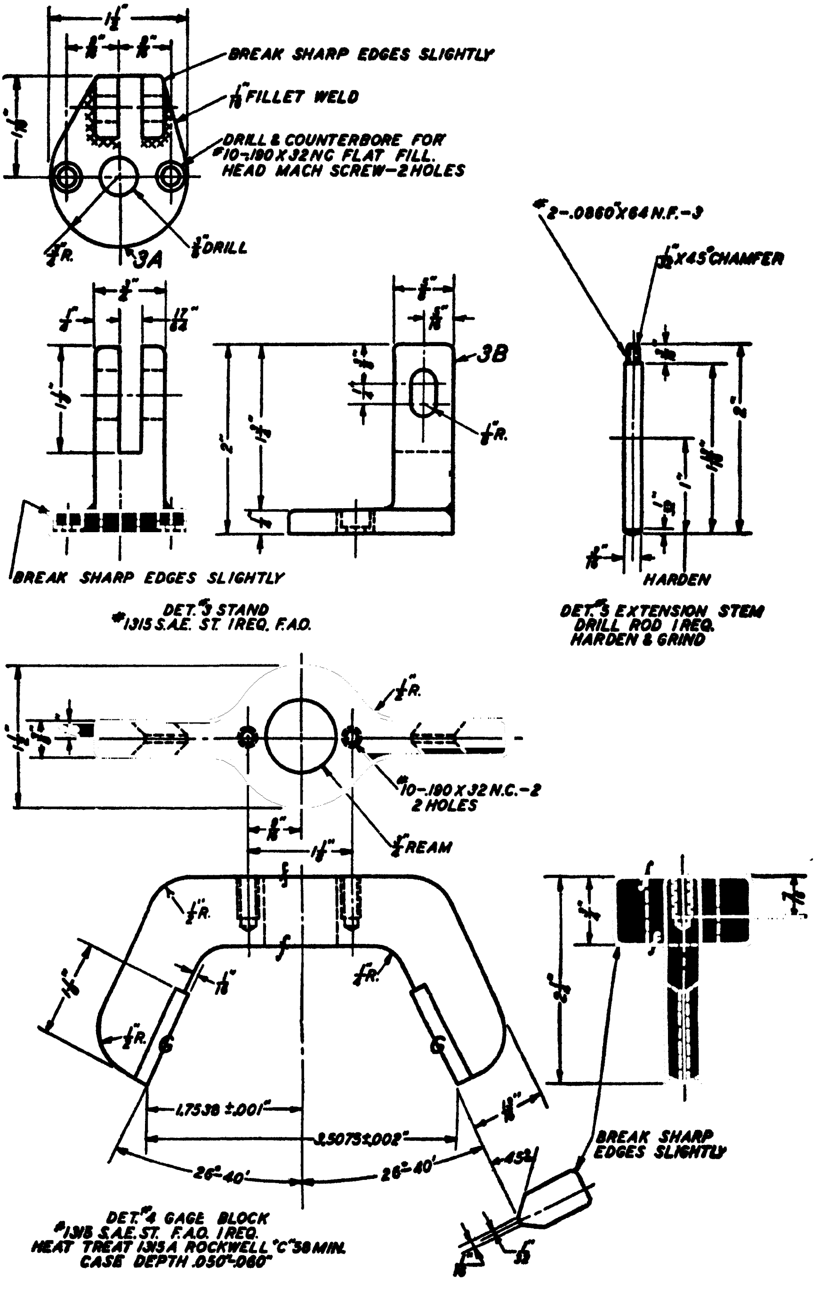
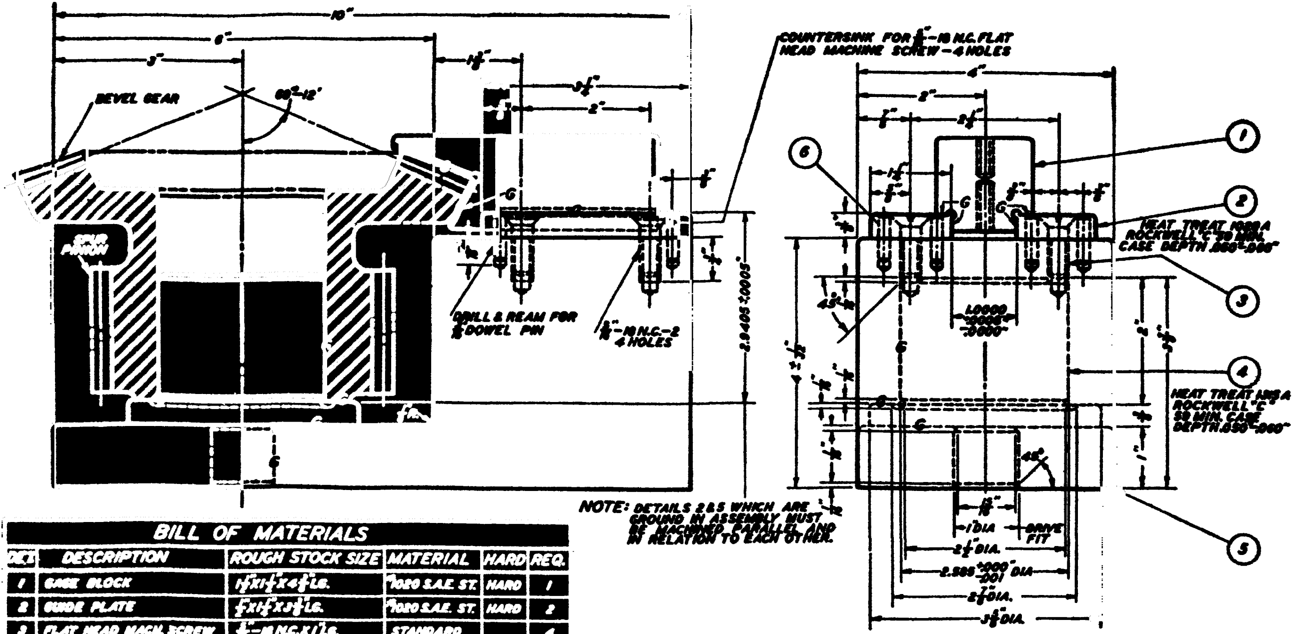

BREAK SHARP EDGES SLIGHTLY
FILLET WELD
DRILL & COUNTERBORE FOR #10-.190X32NC FLAT FILL. HEAD MACH SCREW-2 HOLES
DRILL
3A
3B
BREAK SHARP EDGES SLIGHTLY
DET. #3 STAND
#1315 S.A.E. ST. 1 REQ. F.A.O.
#2-.0860"X64 N.F.-3
X45° CHAMFER
HARDEN
DET. #5 EXTENSION STEM
DRILL ROD 1 REQ.
HARDEN & GRIND
#10-.190X32 N.C.-2
2 HOLES
REAM
6
6
1.7538 ±.001"
3.5075±.002"
26°-40'
26°-40'
45°
BREAK SHARP EDGES SLIGHTLY
DET. #4 GAGE BLOCK
#1315 S.A.E. ST. F.A.O. 1 REQ.
HEAT TREAT 1315A ROCKWELL "C" 58 MIN.
CASE DEPTH .050"-.060"

Fig. 18. Bevel Gear Face Angle Gage Details and Distance


10"
6"
3"
$1\frac{1}{8}$"
$3\frac{1}{4}$"
2"
BEVEL GEAR
88°-12'
SPUR PINION
G
DRILL & REAM FOR $\frac{1}{4}$" DOWEL PIN
$\frac{5}{16}$"-18 N.C.-2 4 HOLES
2.9405±.0005"
COUNTERSINK FOR $\frac{5}{16}$"-18 N.C. FLAT HEAD MACHINE SCREW-4 HOLES
4"
2"
$2\frac{1}{2}$"
$1\frac{1}{4}$"
45°
1.0000 +.0005" -.0000"
45°
1" DIA
DRIVE FIT
$2\frac{1}{2}$" DIA.
2.585 +.000" -.001 DIA
$2\frac{7}{8}$" DIA.
$3\frac{1}{8}$" DIA
1
2
3
4
5
6
HEAT TREAT 1020 A ROCKWELL "C" 58 MIN. CASE DEPTH .050"-.060"
HEAT TREAT 1315 A ROCKWELL "C" 58 MIN. CASE DEPTH .050"-.060"

NOTE: DETAILS 2 & 5 WHICH ARE GROUND IN ASSEMBLY MUST BE MACHINED PARALLEL AND IN RELATION TO EACH OTHER.

NAME-FORM GAGE FOR FINISH TURN BEVEL DIFFERENTIAL BEVEL GEAR AND SPUR PINION.

USED ON BENCH

STAMP TOOL AND PIECE PART NUMBER ON GAGE.

FRACTIONAL DIMENSIONS—LIMITS .010" PLUS OR MINUS.
DECIMAL DIMENSIONS-LIMITS MUST BE HELD AS GIVEN.

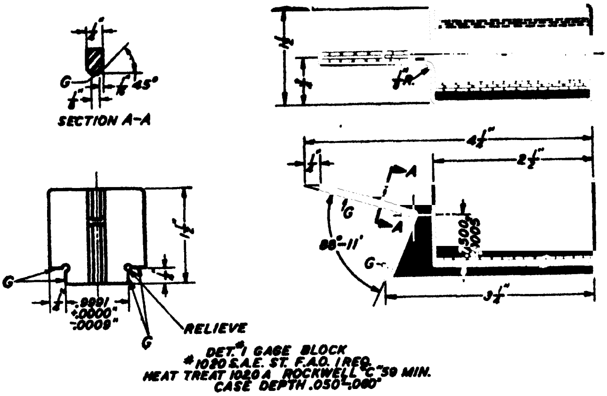
BILL OF MATERIALS

DET.	DESCRIPTION	ROUGH STOCK SIZE	MATERIAL	HARD	REQ.
1	GAGE BLOCK	$1\frac{1}{4}$"X$1\frac{1}{2}$"X$4\frac{3}{4}$" LG.	#1020 S.A.E. ST.	HARD	1
2	GUIDE PLATE	$\frac{1}{2}$"X$1\frac{1}{4}$"X$3\frac{3}{4}$" LG.	#1020 S.A.E. ST.	HARD	2
3	FLAT HEAD MACH. SCREW	$\frac{5}{16}$"-18 N.C.X1" LG.	STANDARD		4
4	LOCATING PLUG	$3\frac{1}{8}$" DIA.X$3\frac{1}{2}$" LG.	#1315 S.A.E. ST.	HARD	1
5	BASE	4"X4"X$10\frac{1}{4}$" LG.	MACH. ST. FORG		1
6	DOWEL PIN	$\frac{1}{4}$" DIA.X$\frac{3}{4}$" LG.	STANDARD		4

Fig. 19. Angles and Distance Gage for Bevel Gear

Distance and Angle Gages. In order to gage the face angle and the distance from the outside diameter to the back of the hub of a differential bevel gear pinion, a gage similar to Fig. 19 is designed. This design is also termed a built-up gage, and its purpose is to check the gear blank after it has been turned and the teeth have been cut prior to heat treatment.

This gage consists of a base which is a machine-steel forging in order to save material. A central plug is designed to be made with a shoulder and pressed into the base of this gage fixture, and the bevel gear is mounted on it. Hardened and ground guide plates are mounted on the base for guiding the gage block, and the gage block has a key that locates in the two guide plates. The correct angle is ground in this gage block, Fig. 20, and the gage block is pushed onto the face of the gear. Sighting shows whether these distances are correct. If too much light shows through, it is apparent that an error has been made in the machining and the piece must be scrapped.



DET. #1 GAGE BLOCK
#1020 S.A.E. ST. F.A.O. 1 REQ.
HEAT TREAT 1020 A ROCKWELL "C" 50 MIN.
CASE DEPTH .050"-.060"

Fig. 20. Working Drawing of Gage Block for Gage Shown in Fig. 19

Gaging Fixtures. There are numerous other types of gages which are designed and made for inspecting and for gaging various types of production. Such designs are numerous; some are very complicated; and it would be impossible to cover all of them in a work of this kind.

In order to become a first-class gage designer and be able to

Fig 21 Gaging Fixture for Checking the Cylinder Blocks of Internal-Combustion Engines

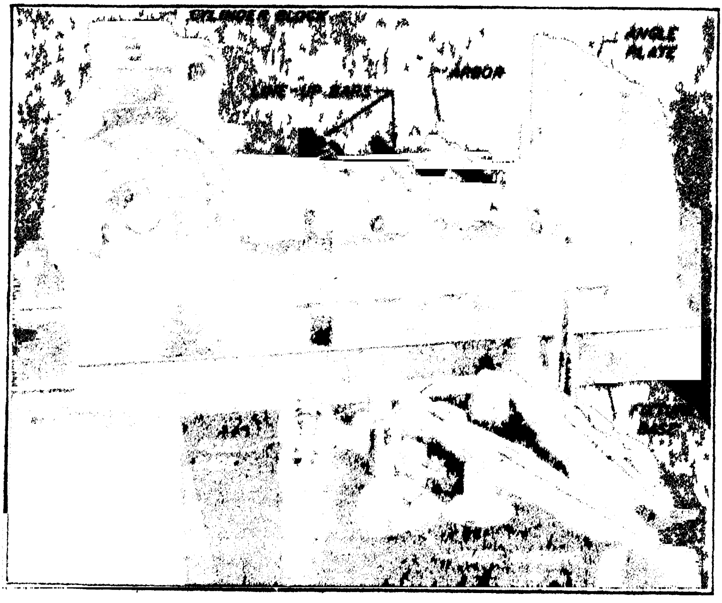


Fig 22 Gaging Fixture Showing Cylinder Block Mounted for Testing

design all types of gages, a number of years of experience and considerable training are required. For example, Fig. 21 is a photograph showing a gage for checking the cylinder block of an internal-combustion engine. This gaging fixture consists of an extremely heavy base with an angle plate on one end and numerous plugs and shafts by which the relation of the cylinder bores to the crankshaft bore, the camshaft bore, etc., can be determined readily. This type of inspection gaging fixture prevents considerable loss of time by reason of the fact that any inaccuracies can be discovered before the entire motor is assembled.

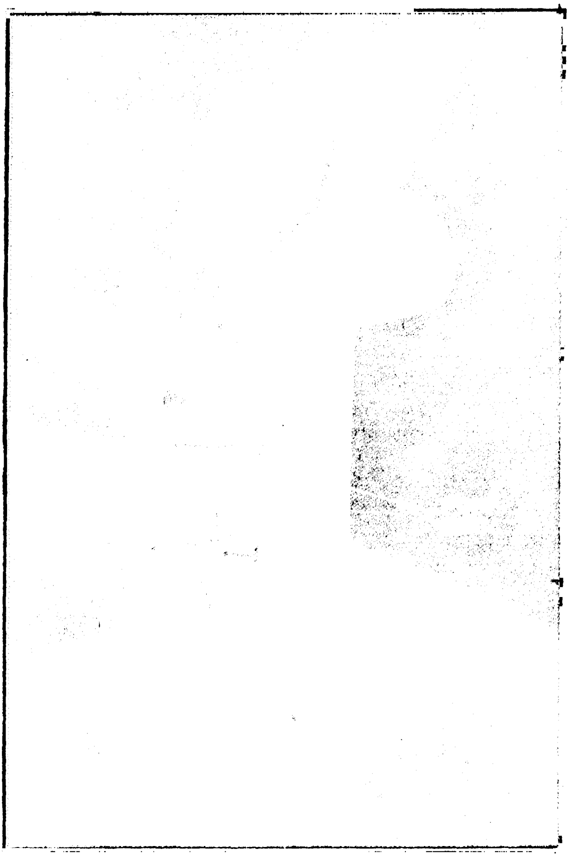


Fig. 23. Comparator Being Used for Inspection of a Gear-Cutting Hob

Courtesy of Jones & Lamson Machine Co., Springfield, Vermont

Fig. 22 shows this gaging fixture with a cylinder block mounted on it, and the various plugs, arbors, etc., are shown in the immediate foreground.

Comparators. In modern manufacturing plants it is necessary to have some means of comparison so that accurate tools that are going to be used for producing parts can be checked to see that they are within the limits required; therefore, a comparator is used. This consists of a machine that throws the shadow of the tool or part to be inspected upon a ground glass on which the outline or limits of accuracy have been drawn many times the actual size of the part to be inspected. In Fig. 23 is shown a comparator. A gear-cutting hob is being inspected to see if the correct angle of tooth has been ground into this hob.

The tool designer is becoming more important in this very complex civilization of ours, as more and more articles of daily use are being made of metals and other materials that require the use of tools. The tool designer must constantly be alert to the improvements in materials and methods. The technological developments of machine tools and materials require that the tool designer be able to use these improvements and constantly strive to design better and cheaper tools, which in turn make possible cheaper and better manufactured articles so that the majority of the people can buy and use them.

QUIZ QUESTIONS

1. What contribution has the use of gages made to modern production methods?
2. What are the three classes of gages used in most of the high-production plants?
3. What types of materials are now used in the making of gages?
4. What is the advantage of the chart shown in Figs. 2A and 2B in designing plug gages?
5. In designing large gages, why should special consideration be given to the matter of weight?
6. What is the advantage of the flat plug gage and where is it generally used?
7. What factor has increased the use of thread gages in modern metalworking plants?
8. When snap gages get up to lengths of 1 foot or more, what special construction features are introduced to keep down weight and the cost of the gage?
9. What are the special purposes or functions of gage arbors?
10. What is the special function of a relation gage?
11. For what type of job are distance and angle gages designed?
12. Describe the comparator and discuss its functions.

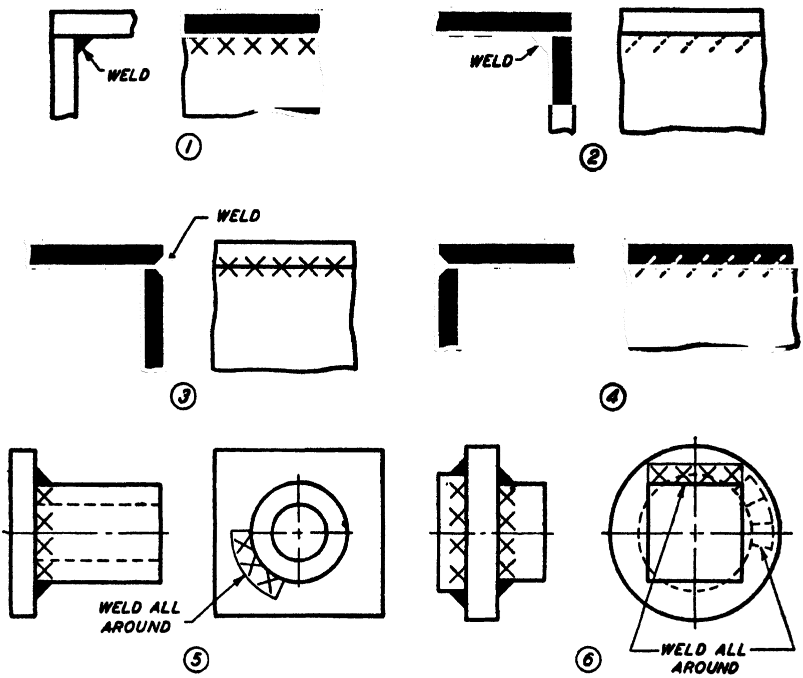
APPENDIX

Common Abbreviations for the Tool Designer

American National	AM. NAT.
American Society of Mechanical Engineers	A.S.M.E.
American Society for Testing Materials	A.S.T.M.
American Society of Tool Engineers	A.S.T.E.
American Standards Association	A.S.A.
Babbitt	BABB.
Blueprint	B/P
Brass	BR.
Bronze	BZ.
Button Head	BUT. HD.
Carburize	CARB.
Cast iron	C.I.
Cast steel	C.S.
Centerline	℄
Chamfer	CHAMF.
Cold-rolled steel	C.R.ST., C.R.S.
Counterbore	C'BORE, C'T'BORE
Countersink	C'SINK, C'T'SINK
Cyanide	CYAN.
Deep	DP.
Detail	DET.
Diameter	DIAM., DIA., D. φ
Dowel pin	D.P.
Drawing	DRWG.
Drill rod	D.R., DR. ROD
Drive fit	D.F.
Drop-forged steel	D.F.S.
Feet	′, FT.
Fillister head	FIL. HD.
Finish	ƒ
Finish all over	F.A.O.
Flat head	FL. HD.
Flat head, bright	FL. HD. BR.
Grind	G., GR., GRD.
Harden	HDN.
Head	HD.
Heat treat	H. TR.
Hexagon head	HEX. HD.
High-speed steel	H.S.S., H.S. ST.
Inch	″, IN.
Inside diameter	I.D.
Locate	LOC.
Machine steel	M.S., MACH. ST.
Material	MAT'L., MAT.
National Coarse	N.C.
National Fine	N.F.
Number	NO.
Open hearth	O.H.
Opposite	OPP.
Outside diameter	O.D.
Pattern	PATT.
Plate	PL.
Pound	#, LB.
Press fit	P.F.
Radius	R.
Required	REQ'D., REQ.
Rockwell	ROCK.
Round head	RD. HD.
Round head, blued	RD. HD. BL.
Running fit	R.F.
Screw	SCR.
Section	SEC., SECT.
Slip fit	S.F.
Snug fit	SN. F.
Society of Automotive Engineers	S.A.E.
Socket	SOCK., SOC.
Socket-head screw	SOC. HD. SCR.
Spherical radius	SPH. R., S.R.
Spotface	S'FACE
Spot weld	S/W
Square head	SQ. HD.
Standard	STD., ST'D
Steel	ST., STL.
Stock	STK.
Thread	THD., TH.
Tool steel	T.S., T. ST.
Working fit	W.F.

If a line on a drawing is not drawn to scale, it is dimensioned correctly and the dimension is underscored with a wavy line to call attention to this fact.

SYMBOLS FOR WELDS



1, Corner Weld, Near Side; *2*, Corner Weld, Far Side; *3*, V-Weld, Near Side; *4*, V-Weld, Far Side; *5*, All-around Weld on Near Side; *6*, All-around Welds on Near Side Are in Solid Lines, those on Far Side Are in Broken Lines

AMERICAN STANDARD—NATIONAL STANDARD

SCREW THREADS*

For Bolts, Nuts, Machine Screws, and Threaded Parts

This standard covers the dimensional specifications for American Standard Screw Threads applicable to bolts, machine screws, nuts, tapped holes, and other threaded parts. It is a revision of the original American Standard approved in May, 1924, by the American Standards Association. The changes and additions included are based on the requirements of industry as reflected by comments received since the release of the 1924 publication and also upon the information obtained through an extensive survey of American industrial screw thread practice conducted in 1931 by the Sectional Committee on Standardization and Unification of Screw Threads with the cooperation of the National Bureau of Standards.

Form of Thread

The form of thread profile as specified herein, and known previously as the "United States Standard" or "Sellers' Profile," is adopted and shall hereafter be known as the American National Form of Thread.

Specifications. The *basic angle* of thread between the sides of the thread measured in an axial plane shall be 60 degrees. The line bisecting this 60 degree angle shall be perpendicular to the axis of the screw thread.

The *basic width* of flat at the root and crest of the thread form is found as follows:

$$F = \frac{1}{8} \times p \text{ or } 0.125 \times p$$

The *basic depth* of the thread form, Fig. A, is found as follows:

$$h = 0.649519 \times p = \frac{0.649519}{n}$$

where p = pitch in inches
n = number of threads per inch.

Screw-Thread Series

Five series of screw threads are covered by this standard, differing from one another in the diameter-pitch relations of the threads included but all employing the American National form of thread. These series are: the Coarse-Thread, the Fine-Thread, and three special series, the 8-Pitch-,.12-Pitch-, and 16-Pitch-Thread. The Coarse-Thread and Fine-Thread Series are presented in detail.

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*This article is printed through courtesy of the Society of Automotive Engineers and The American Society of Mechanical Engineers.

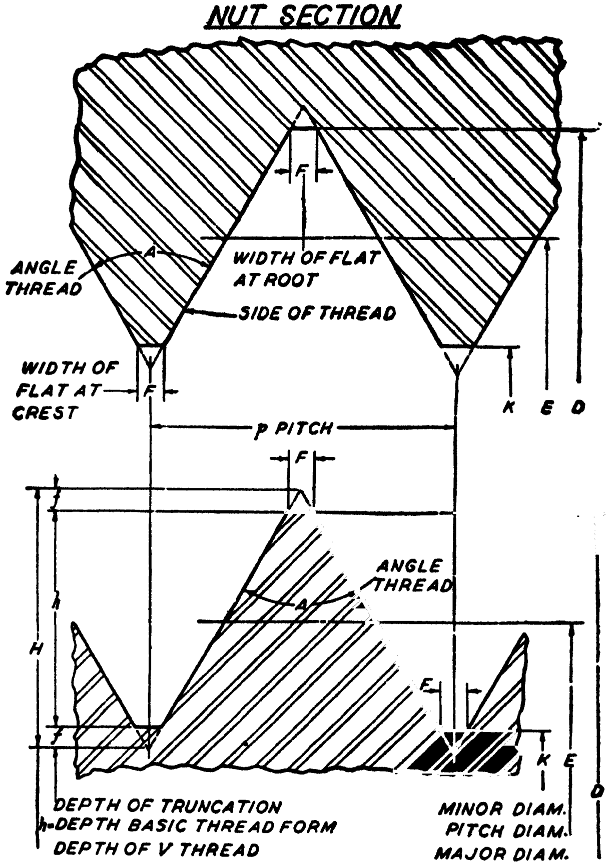

Fig. A. American National Form of Thread

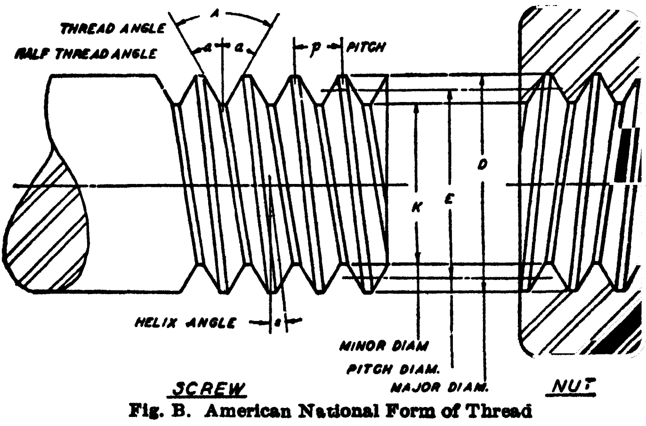

Fig. B. American National Form of Thread

Table 100. Coarse-Thread Series—General Dimensions

The American Standard Coarse-Thread Series is recommended for general use.

IDENTIFICATION		BASIC DIAMETERS			THREAD DATA					
Size	Threads per Inch (n)	Major Diameter (D)	Pitch Diameter (E)	Minor Diameter (K)	Pitch[1] (p)	Basic Depth of Thread (h)	Basic Width of Flat $p/8$	Minimum Width of Flat at Major Diameter of Nut $p/24$	Helix Angle at Basic Pitch Diameter S (Deg—Min)	Basic[2] Area of Section at Root of Thread $\frac{\pi K^2}{4}$ (Sq. In.)
1	64	0.0730	0.0629	0.0527	0.0156250	0.01015	0.00195	0.00065	4—31	0.0022
2	56	0.0860	0.0744	0.0628	0.0178571	0.01160	0.00223	0.00074	4—22	0.0031
3	48	0.0990	0.0855	0.0719	0.0208333	0.01353	0.00260	0.00087	4—26	0.0041
4	40	0.1120	0.0958	0.0795	0.0250000	0.01624	0.00312	0.00104	4—45	0.0050
5	40	0.1250	0.1088	0.0925	0.0250000	0.01624	0.00312	0.00104	4—11	0.0067
6	32	0.1380	0.1177	0.0974	0.0312500	0.02030	0.00391	0.00130	4—50	0.0075
8	32	0.1640	0.1437	0.1234	0.0312500	0.02030	0.00391	0.00130	3—58	0.0120
10	24	0.1900	0.1629	0.1359	0.0416667	0.02706	0.00521	0.00174	4—39	0.0145
12	24	0.2160	0.1889	0.1619	0.0416667	0.02706	0.00521	0.00174	4—1	0.0206
¼	20	0.2500	0.2175	0.1850	0.0500000	0.03248	0.00625	0.00208	4—11	0.0269
5/16	18	0.3125	0.2764	0.2403	0.0555556	0.03608	0.00694	0.00231	3—40	0.0454
⅜	16	0.3750	0.3344	0.2938	0.0625000	0.04059	0.00781	0.00260	3—24	0.0678
7/16	14	0.4375	0.3911	0.3447	0.0714286	0.04639	0.00893	0.00298	3—20	0.0933
½	13	0.5000	0.4500	0.4001	0.0769231	0.04996	0.00962	0.00321	3—7	0.1257
9/16	12	0.5625	0.5084	0.4542	0.0833333	0.05413	0.01042	0.00347	2—59	0.1620
⅝	11	0.6250	0.5660	0.5069	0.0909091	0.05905	0.01136	0.00379	2—56	0.2018
¾	10	0.7500	0.6850	0.6201	0.1000000	0.06495	0.01250	0.00417	2—40	0.3020
⅞	9	0.8750	0.8028	0.7307	0.1111111	0.07217	0.01389	0.00463	2—31	0.4193
1	8	1.0000	0.9188	0.8376	0.1250000	0.08119	0.01562	0.00521	2—29	0.5510
1⅛	7	1.1250	1.0322	0.9394	0.1428571	0.09279	0.01786	0.00595	2—31	0.6931
1¼	7	1.2500	1.1572	1.0644	0.1428571	0.09279	0.01786	0.00595	2—15	0.8898
1⅜	6	1.3750	1.2667	1.1585	0.1666667	0.10825	0.02083	0.00694	2—24	1.0541
1½	6	1.5000	1.3917	1.2835	0.1666667	0.10825	0.02083	0.00694	2—11	1.2938
1¾	5	1.7500	1.6201	1.4902	0.2000000	0.12990	0.02500	0.00833	2—15	1.7441
2	4½	2.0000	1.8557	1.7113	0.2222222	0.14434	0.02778	0.00926	2—11	2.3001
2¼	4½	2.2500	2.1057	1.9613	0.2222222	0.14434	0.02778	0.00926	1—55	3.0212
2½	4	2.5000	2.3376	2.1752	0.2500000	0.16238	0.03125	0.01042	1—57	3.7161
2¾	4	2.7500	2.5876	2.4252	0.2500000	0.16238	0.03125	0.01042	1—46	4.6194
3	4	3.0000	2.8376	2.6752	0.2500000	0.16238	0.03125	0.01042	1—36	5.6209
3¼	4	3.2500	3.0876	2.9252	0.2500000	0.16238	0.03125	0.01042	1—29	6.7205
3½	4	3.5000	3.3376	3.1752	0.2500000	0.16238	0.03125	0.01042	1—22	7.9183
3¾	4	3.7500	3.5876	3.4252	0.2500000	0.16238	0.03125	0.01042	1—16	9.2143
4	4	4.0000	3.8376	3.6752	0.2500000	0.16238	0.03125	0.01042	1—11	10.6084

All dimensions given in inches.

[1] This column is given to seven decimal places for computation purposes only.

[2] These basic areas are given as information to be used in roughly computing the ultimate strength of the thread. The actual strength, computed from the ultimate strength of the material, will depend on the actual cross-sectional area at the root of the thread and an increment contributed by the thread itself, depending on the material and process of manufacture.

Table 101. Fine-Thread Series—General Dimensions

The American Standard Fine-Thread Series is recommended for use where special conditions require a fine thread.

Identification		Basic Diameters			Thread Data					
Size	Threads per inch (n)	Major Diameter (D)	Pitch Diameter (E)	Minor Diameter (K)	Pitch[1] (p)	Basic Depth of Thread (h)	Basic Width of Flat $p/8$	Minimum Width of Flat at Major Diameter of Nut $p/24$	Helix Angle at Basic Pitch Diameter S (Deg—Min)	Basic[2] Area of Section at Root of Thread $\frac{\pi K^2}{4}$ (Sq. In.)
0	80	0.0600	0.0519	0.0438	0.0125000	0.00812	0.00156	0.00052	4—23	0.0015
1	72	0.0730	0.0640	0.0550	0.0138889	0.00902	0.00174	0.00058	3—57	0.0024
2	64	0.0860	0.0759	0.0657	0.0156250	0.01015	0.00195	0.00065	3—45	0.0034
3	56	0.0990	0.0874	0.0758	0.0178571	0.01160	0.00223	0.00074	3—43	0.0045
4	48	0.1120	0.0985	0.0849	0.0208333	0.01353	0.00260	0.00087	3—51	0.0057
5	44	0.1250	0.1102	0.0955	0.0227273	0.01476	0.00284	0.00095	3—45	0.0072
6	40	0.1380	0.1218	0.1055	0.0250000	0.01624	0.00312	0.00104	3—44	0.0087
8	36	0.1640	0.1460	0.1279	0.0277778	0.01804	0.00347	0.00116	3—28	0.0128
10	32	0.1900	0.1697	0.1494	0.0312500	0.02030	0.00391	0.00130	3—21	0.0175
12	28	0.2160	0.1928	0.1696	0.0357143	0.02320	0.00446	0.00149	3—22	0.0226
1/4	28	0.2500	0.2268	0.2036	0.0357143	0.02320	0.00446	0.00149	2—52	0.0326
5/16	24	0.3125	0.2854	0.2584	0.0416667	0.02706	0.00521	0.00174	2—40	0.0524
3/8	24	0.3750	0.3479	0.3209	0.0416667	0.02706	0.00521	0.00174	2—11	0.0809
7/16	20	0.4375	0.4050	0.3725	0.0500000	0.03248	0.00625	0.00208	2—15	0.1090
1/2	20	0.5000	0.4675	0.4350	0.0500000	0.03248	0.00625	0.00208	1—57	0.1486
9/16	18	0.5625	0.5264	0.4903	0.0555556	0.03608	0.00694	0.00231	1—55	0.1888
5/8	18	0.6250	0.5889	0.5528	0.0555556	0.03608	0.00694	0.00231	1—43	0.2400
3/4	16	0.7500	0.7094	0.6688	0.0625000	0.04059	0.00781	0.00260	1—36	0.3513
7/8	14	0.8750	0.8286	0.7822	0.0714286	0.04639	0.00893	0.00298	1—34	0.4805
1	14	1.0000	0.9536	0.9072	0.0714286	0.04639	0.00893	0.00298	1—22	0.6464
1 1/8	12	1.1250	1.0709	1.0167	0.0833333	0.05413	0.01042	0.00347	1—25	0.8118
1 1/4	12	1.2500	1.1959	1.1417	0.0833333	0.05413	0.01042	0.00347	1—16	1.0238
1 3/8	12	1.3750	1.3209	1.2667	0.0833333	0.05413	0.01042	0.00347	1—9	1.2602
1 1/2	12	1.5000	1.4459	1.3917	0.0833333	0.05413	0.01042	0.00347	1—3	1.5212

All dimensions given in inches.

[1] This column is given to seven decimal places for computation purposes only.

[2] These basic areas are given as information to be used in roughly computing the ultimate strength of the thread. The actual strength, computed from the ultimate strength of the material, will depend on the actual cross-sectional area at the root of the thread and an increment contributed by the thread itself depending on the material and process of manufacture.

Class 2 Fit. This class is defined and specified as follows:

The minimum nut is basic.

The maximum screw is basic.

The tolerance on the nut is plus.

The tolerance on the screw is minus.

The allowance between the pitch diameters of the maximum screw and the minimum nut is zero for all pitches and all diameters.

The pitch-diameter tolerances for a screw or nut of a given pitch in the Coarse- and Fine-Thread Series are as specified in Table 102.

Class 3 Fit. This class is defined and specified as follows:

The minimum nut is basic.

The maximum screw is basic.

The tolerance on the nut is plus.

The tolerance on the screw is minus.

The allowance between the pitch diameters of the maximum screw and the minimum nut is zero for all pitches and all diameters.

The pitch diameter tolerances for a screw or nut of a given pitch in the Coarse- and Fine-Thread Series are as specified in Table 103.

Table 102. Class 2 Fit

Allowances and Tolerances for Screws and Nuts (Coarse- and Fine-Thread Series Only)

Threads per Inch	Allowance (Inches)	Pitch-Diam. Tolerances (Inches)	Lead[1] Variation (Inches)	Variation[2] in ½ Angle (Deg—Min)
80	0.0000	0.0017	0.0005	2—36
72	0.0000	0.0018	0.0005	2—28
64	0.0000	0.0019	0.0005	2—19
56	0.0000	0.0020	0.0006	2—8
48	0.0000	0.0022	0.0006	2—1
44	0.0000	0.0023	0.0007	1—56
40	0.0000	0.0024	0.0007	1—50
36	0.0000	0.0025	0.0007	1—43
32	0.0000	0.0027	0.0008	1—39
28	0.0000	0.0031	0.0009	1—39
24	0.0000	0.0033	0.0010	1—31
20	0.0000	0.0036	0 0010	1—22
18	0.0000	0.0041	0 0012	1—25
16	0.0000	0.0045	0.0013	1—22
14	0.0000	0.0049	0.0014	1—19
13	0.0000	0.0052	0.0015	1—17
12	0.0000	0.0056	0.0016	1—17
11	0.0000	0.0059	0.0017	1—14
10	0.0000	0.0064	0.0018	1—13
9	0.0000	0.0070	0.0020	1—12
8	0.0000	0.0076	0.0022	1—10
7	0.0000	0.0085	0.0025	1—8
6	0.0000	0.0101	0.0029	1—9
5	0.0000	0.0116	0.0033	1—6
4 ½	0.0000	0.0127	0.0037	1—5
4	0.0000	0.0140	0.0040	1—4

[1] Variation in lead between any two-threads not farther apart than the length of engagement which would absorb one-half the pitch diameter tolerance.

[2] Variation in half angle which would absorb one-half the pitch diameter tolerance.

Table 103. Class 3 Fit

Allowances and Tolerances for Screws and Nuts (Coarse- and Fine-Thread Series Only)

Threads per Inch	Allowance (Inches)	Pitch-Diam. Tolerances (Inches)	Lead[1] Variation (Inches)	Variation[2] in ½ Angle (Deg—Min)
80	0.0000	0.0013	0.0004	1—59
72	0.0000	0.0013	0.0004	1—47
64	0.0000	0.0014	0.0004	1—43
56	0.0000	0.0015	0.0004	1—36
48	0.0000	0.0016	0.0005	1—28
44	0.0000	0.0016	0.0005	1—21
40	0.0000	0.0017	0.0005	1—18
36	0.0000	0.0018	0.0005	1—14
32	0.0000	0.0019	0.0005	1—10
28	0.0000	0.0022	0.0006	1—11
24	0.0000	0.0024	0.0007	1—6
20	0.0000	0.0026	0.0008	1—0
18	0.0000	0.0030	0.0009	1—2
16	0.0000	0.0032	0.0009	0—59
14	0.0000	0.0036	0.0010	0—58
13	0.0000	0.0037	0.0011	0—55
12	0.0000	0.0040	0.0012	0—55
11	0.0000	0.0042	0.0012	0—53
10	0.0000	0.0045	0.0013	0—52
9	0.0000	0.0049	0.0014	0—51
8	0.0000	0.0054	0.0016	0—50
7	0.0000	0.0059	0.0017	0—47
6	0.0000	0.0071	0.0020	0—49
5	0.0000	0.0082	0.0024	0—47
4 ½	0.0000	0.0089	0.0026	0—46
4	0.0000	0.0097	0.0028	0—44

[1] Variation in lead between any two-threads not farther apart than the length of engagement which would absorb one-half the pitch diameter tolerance.

[2] Variation in half angle which would absorb one-half the pitch diameter tolerance.

TERMINOLOGY

Terms Relating to Threads

Screw Thread: A ridge of uniform section in the form of a helix on the external or internal surface of a cylinder.

External Thread: A thread on the outside of a member. See Fig. B.

Internal Thread: A thread on the inside of a member.

Major Diameter: The largest diameter of a screw thread. The term major diameter applies to both internal and external threads and replaces the term "outside diameter" as applied to the thread of a screw and also the term "full diameter" as applied to the thread of a nut.

Minor Diameter: The smallest diameter of a screw thread. The term minor diameter applies to both internal and external threads and replaces the terms "core diameter" and "root diameter" as applied to the thread of a screw and also the term "inside diameter" as applied to the thread of a nut.

Pitch Diameter: The diameter of an imaginary cylinder the surface of which would pass through the threads at such points as to make equal the width of the threads and the width of the spaces cut by the surface of the cylinder.

Pitch: The distance from a point on a screw thread to a corresponding point on the next thread measured parallel to the axis.

$$\text{Pitch (in inches)} = \frac{1}{\text{Number of threads per inch}}$$

Lead: The distance a screw thread advances axially in one turn. On a single-thread screw, the lead and pitch are identical; on a double-thread screw, the lead is twice the pitch; on a triple-thread screw, the lead is three times the pitch, etc.

Angle of Thread: The angle included between the sides of the thread measured in an axial plane.

Half-Angle: The angle included between a side of the thread and the normal to the axis, measured in an axial plane.

Helix Angle: The angle made by the helix of the thread at the pitch diameter with a plane perpendicular to the axis.

Crest: The top surface joining the two sides of a thread.

Root: The bottom surface joining the sides of two adjacent threads

Side. The surface of the thread which connects the crest with the root.

Axis of a Screw. The longitudinal central line through the screw

Depth of Thread: The distance between the crest and the root of thread measured normal to the axis.

Length of Engagement: The length of contact between two mating parts, measured axially.

Depth of Engagement The depth of thread contact of two mating parts, measured radially

SYMBOLS

Specifications on Drawings, etc. In the past, when the United States Standard, or Society of Automotive Engineers' Standards, were followed one would specify a ½-inch thread thus ½"-13 U S S Th When using the American Standard, the above specification would be changed to ½"-13 NC-2.

The ½" stands for the diameter; 13 for the number of threads per inch; N for National; C for coarse thread; and 2 indicating the class of fit desired. For a thread machined in a hole the specification would read thus: Tap ½"-13 NC-2 The above discussion applies to the American Standard Coarse-Thread Series

If a fine thread is to be cut on a piece part having a ½-inch diameter and a left-hand thread, the specification would be as follows, ½"-20NF-2LH. The N being used for National; F for fine thread; 2 for the class of fit; LH for left-hand thread. The above discussion applies to the American Standard Fine-Thread Series.

The special series or The American Standard 8-Pitch, 12-Pitch, and 16-Pitch-Thread Series would be specified as follows when it is desired to have a 5" diameter rod threaded having an 8-pitch thread, 12-pitch or 16-pitch thread, and a Class 3 Fit. 5"-8N-3, 5"-12N-3, 5"-16N-3.

SCREW-THREAD FITS

Classification. Four classes of screw-thread fit are provided: Class 1, Class 2, Class 3, and Class 4. Of these Class 1 fit is the loosest and Class 4 the closest, with Classes 2 and 3 graduated between. These four fits are produced by the application of specific tolerances or tolerances together with allowances, the latter being applicable in the case of the screw only, to the basic pitch diameter of the thread which is the same for both internal and external threads of like size and pitch. The tolerances throughout are applied *plus* to the hole and *minus* to the screw.

Class 2 Fit. This class is a much higher quality of fit than Class 1 and is used extensively where interchangeability is desired. In some cases screws are made, that fit an internal thread very closely, or with a fit that has no play or looseness, such depending upon the accuracy of the pitch diameter of external and internal thread. This class of fit is recommended for general use.

Class 3 Fit. This class is one that is not used as extensively as Class 2, for it represents an exceptionally high grade of commercially threaded product and is recommended only in cases where the high cost of precision tools and continual checking of tools and product is warranted.

Class 4 Fit. This class is one that is not used on high production work and it is only used for selective assembly. This is a much higher grade of fit than Class 3, which is mostly used in automotive work. Class 4 Fit is used in airplane plants where a fine snug fit is required on various aircraft piece parts.

The efficiency of any screw, whether it be on a bolt or a screw used in connection with a machine for feeding a slide of some kind, depends on the fit of that screw Bolts must have accurately cut threads so that their power to hold pieces together is not impaired. Thus if a bolt is to be correctly made, its pitch diameter must coincide with the pitch diameter of the nut.

The following material on fittings of threads is taken from "Machine Shop Operations" published by the American Technical Society

A study of Figs. 1 to 4 will readily show the student correct and incorrect fittings of threads.

The manner in which threads fit when two surfaces are placed together is very important. In a case of a lead screw on a lathe, for instance, the sides of the threads on the screw must exactly match the sides of the thread in the nut, otherwise there will be excessive wear, especially on the nut, and the machine will not do good work. In the case of a bolt which is designed to carry a certain load, the thread must fit the nut or the hole, as the case may be, otherwise the holding power of the bolt will be greatly reduced. The diagrams shown in Figs. 1 to 4 illustrate this point and it is recommended that the student study them carefully

A study of the diagrams contained in Figs. 1 to 4 will show why a good fit between the threads on a bolt and those in the nut is important. A well-fitted thread will prevent the nut from loosening and will also increase the holding strength of the bolt very materially.

A good fit may be defined as one where the pitch diameter of the thread on the bolt coincides with the pitch diameter of the thread in the nut and where the sides of the thread on the bolt are cut at the same angle as those on the threads in the nut. The amount of clearance at the top or bottom of the thread should be only enough to allow the nut to turn readily on the bolt in order to give the maximum amount of bearing surface on the threads

The man in the shop decides about the fit of a bolt in a nut by the manner in which the two go together. If the bolt screws into the nut or into a blind hole freely but with a snug fit and no shake, he knows by a sense of "feel" that the two threads fit. This knowledge of "feel" of a well-fitted thread is especially important when assembling machinery and comes only through practice. A beginner should make it a point to learn this very early in his career, so that when cutting threads either with a tap or otherwise, he will be able to know when the threads are well fitted.

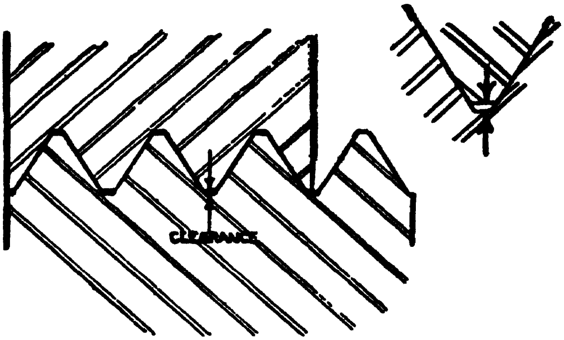

Fig. 1. Diagram illustrating a good fit between two threaded surfaces. Note the equal clearance at top and bottom of the thread in the nut and the screw. Also note the sloping sides of the threads on the screw and in the nut are the same, so that a perfect bearing exists between the two sides of the threads. The fit between the sides of the threads is important.

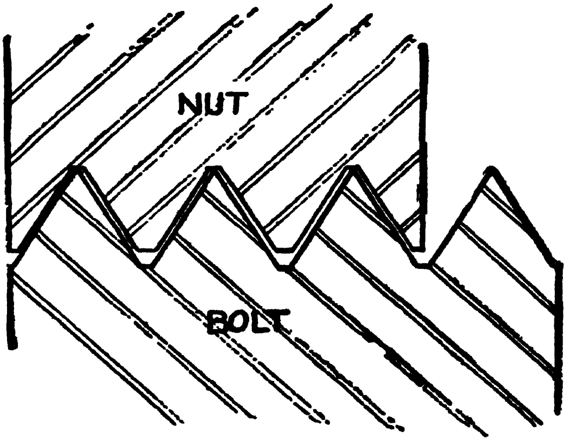

Fig. 2. Diagram showing a poor fit between two threaded surfaces. This condition will exist when the threads on the bolt are cut too small or those in the nut are cut too large. Note the large clearance at the bottom of the thread. This weakens the holding power of the nut and the screw very materially. In a well-fitting thread, the pitch lines of the two threads coincide, or come together.

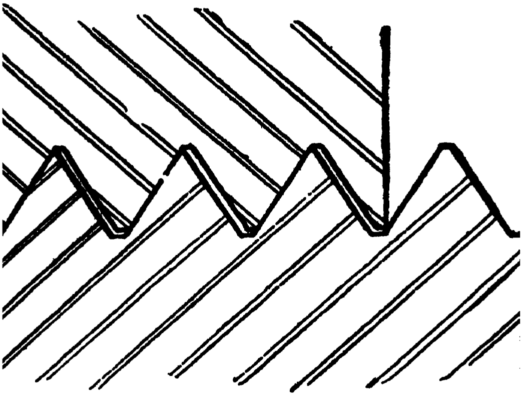

Fig. 3. Here the thread in the nut is correct but the one on the screw has been turned thin and is oversize so that the top of the thread on the screw is binding at the bottom of the thread in the nut. This is a bad condition as it will cause the nut to bind on the screw and perhaps strip the thread.

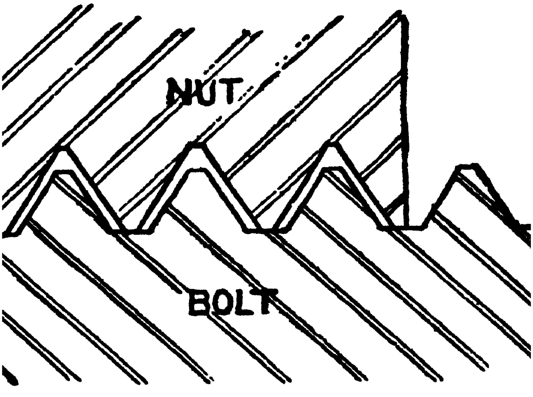

Fig. 4. Diagram showing the effects of filing the tops of the threads on the bolt. Note that almost half the thread on the screw has been filed away and that the thread is too thin. A screw with this kind of a thread on it will loosen very quickly and its holding power will be greatly reduced. A fit of this kind will invariably cause trouble.

Table 104. Tap Drill Sizes

(American National Form Threads—Fine-Thread Series)

Size	Threads per Inch	Major Diameter	Commercial Tap Drill to Produce Approx. 75% Full Thread	Decimal Equivalent of Tap Drill
0	80	0.0600	3/64	0.0469
1	72	0.0730	53	0.0595
2	64	0.0860	50	0.0700
3	56	0.0990	45	0.0820
4	48	0.1120	42	0.0935
5	44	0.1250	37	0.1040
6	40	0.1380	33	0.1130
8	36	0.1640	29	0.1360
10	32	0.1900	21	0.1590
12	28	0.2160	14	0.1820
1/4	28	0.2500	3	0.2130
5/16	24	0.3125	I	0.2720
3/8	24	0.3750	Q	0.3320
7/16	20	0.4375	25/64	0.3906
1/2	20	0.5000	29/64	0.4531
9/16	18	0.5625	33/64	0.5156
5/8	18	0.6250	37/64	0.5781
3/4	16	0.7500	11/16	0.6875
7/8	14	0.8750	13/16	0.8125
1	14	1.0000	15/16	0.9375
1 1/8	12	1.1250	1 3/64	1.0469
1 1/4	12	1.2500	1 11/64	1.1719
1 3/8	12	1.3750	1 19/64	1.2969
1 1/2	12	1.5000	1 27/64	1.4219

Table 105. Tap Drill Sizes

(American National Form Threads—Coarse-Thread Series)

Size	Threads per Inch	Major Diameter	Commercial Tap Drill to Produce Approx. 75% Full Thread	Decimal Equivalent of Tap Drill
1	64	0.0730	53	0.0595
2	56	0.0860	50	0.0700
3	48	0.0990	47	0.0785
4	40	0.1120	43	0.0890
5	40	0.1250	38	0.1015
6	32	0.1380	36	0.1065
8	32	0.1640	29	0.1360
10	24	0.1900	25	0.1495
12	24	0.2160	16	0.1770
1/4	20	0.2500	7	0.2010
5/16	18	0.3125	F	0.2570
3/8	16	0.3750	5/16	0.3125
7/16	14	0.4375	U	0.3680
1/2	13	0.5000	27/64	0.4219
9/16	12	0.5625	31/64	0.4844
5/8	11	0.6250	17/32	0.5312
3/4	10	0.7500	21/32	0.6562
7/8	9	0.8750	49/64	0.7656
1	8	1.0000	7/8	0.8750
1 1/8	7	1.1250	63/64	0.9844
1 1/4	7	1.2500	1 7/64	1.1094
1 3/8	6	1.3750	1 7/32	1.2187
1 1/2	6	1.5000	1 11/32	1.3437
1 3/4	5	1.7500	1 9/16	1.5625
2	4 1/2	2.0000	1 25/32	1.7812
2 1/4	4 1/2	2.2500	2 1/32	2.0312
2 1/2	4	2.5000	2 1/4	2.2500
2 3/4	4	2.7500	2 1/2	2.5000

TABLE 106

Decimal Equivalents of Fractions of an Inch

				1/64	0.015625					33/64	0.515625
			1/32		0.03125				17/32		0.53125
				3/64	0.046875					35/64	0.546875
		1/16			0.0625			9/16			0.5625
				5/64	0.078125					37/64	0.578125
			3/32		0.09375				19/32		0.59375
				7/64	0.109375					39/64	0.609375
	1/8				0.125		5/8				0.625
				9/64	0.140625					41/64	0.640625
			5/32		0.15625				21/32		0.65625
				11/64	0.171875					43/64	0.671875
		3/16			0.1875			11/16			0.6875
				13/64	0.203125					45/64	0.703125
			7/32		0.21875				23/32		0.71875
				15/64	0.234375					47/64	0.734375
1/4					0.250	3/4					0.750
				17/64	0.265625					49/64	0.765625
			9/32		0.28125				25/32		0.78125
				19/64	0.296875					51/64	0.796875
		5/16			0.3125			13/16			0.8125
				21/64	0.328125					53/64	0.828125
			11/32		0.34375				27/32		0.84375
				23/64	0.359375					55/64	0.859375
	3/8				0.375		7/8				0.875
				25/64	0.390625					57/64	0.890625
			13/32		0.40625				29/32		0.90625
				27/64	0.421875					59/64	0.921875
		7/16			0.4375			15/16			0.9375
				29/64	0.453125					61/64	0.953125
			15/32		0.46875				31/32		0.96875
				31/64	0.484375					63/64	0.984375
1/2					0.500						

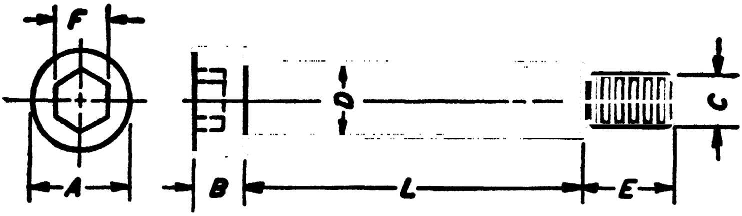

Table 107. Dimensions of Stripper Bolts

D	A	B	C		D	F across Flats
			Diameter	Coarse (American Standard) Threads		
⅜	9/16	¼	5/16	18	½	3/16
½	¾	5/16	⅜	16	⅝	¼
⅝	⅞	⅜	½	13	¾	5/16
¾	1	½	⅝	11	⅞	⅜

Diameter D

⅜"	½"	⅝"	¾"
1*	1*	. . .	. . .
1¼	1¼	1¼*	. . .
1½	1½	1½	1½*
1¾	1¾	1¾	1¾
2	2	2	2
2¼	2¼	2¼	2¼
2½	2½	2½	2½
2¾	2¾	2¾	2¾
3	3	3	3
3¼	3¼	3¼	3¼
3½	3½	3½	3½
3¾	3¾	3¾	3¾
4	4	4	4
. . .	4¼	4¼	4¼
. . .	4½	4½	4½
. . .	4¾	4¾	4¾
. . .	5	5	5
. . .	. . .	5½	5½
. . .	. . .	6	6
. . .	. . .	. . .	6½
. . .	. . .	. . .	7

*Length (L).

Courtesy of Mac-It Parts Company, Lancaster, Pa.

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Useful Information

To find the circumference of a circle, multiply the diameter by 3.1416.

To find the diameter of a circle, multiply the circumference by .31831.

To find the area of a circle, multiply the square of the diameter by .7854.

The radius of a circle × 6.283185 = the circumference.

The square of the circumference of a circle × .07958 = the area.

Half the circumference of a circle × half its diameter = the area.

The circumference of a circle × .159155 = the radius.

The square root of the area of a circle × .56419 = the radius.

The square root of the area of a circle × 1.12838 = the diameter.

To find the diameter of a circle equal in area to a given square, multiply a side of the square by 1.12838.

To find the side of a square equal in area to a given circle, multiply the diameter by .8862.

To find the side of a square inscribed in a circle, multiply the diameter by .7071.

To find the side of a hexagon inscribed in a circle, multiply the diameter of the circle by .500.

To find the diameter of a circle inscribed in a hexagon, multiply a side of the hexagon by 1.7321.

To find the side of an equilateral triangle inscribed in a circle, multiply the diameter of the circle by .866.

To find the diameter of a circle inscribed in an equilateral triangle, multiply a side of the triangle by .57735.

To find the area of the surface of a ball (sphere), multiply the square of the diameter by 3.1416.

To find the volume of a ball (sphere), multiply the cube of the diameter by .5236.

Doubling the diameter of a pipe increases its capacity four times.

To find the pressure in pounds per square inch at the base of a column of water, multiply the height of the column in feet by .433.

A gallon of water (U. S. Standard) weighs 8.336 pounds and contains 231 cubic inches. A cubic foot of water contains 7½ gallons, 1728 cubic inches, and weighs 62.425 pounds at a temperature of about 39° F. These weights change slightly above and below this temperature.

Tables and Data

In accordance with the standard practice approved by the American Standards Association, the ratio 25.4 mm = 1 inch is used for converting millimeters to inches. This factor varies only two millionths of an inch from the more exact factor 25.40005 mm, a difference so small as to be negligible for industrial length measurements.

Metric Measures

The metric unit of length is the meter = 39.37 inches.

The metric unit of weight is the gram = 15.432 grains.

The following prefixes are used for sub-divisions and multiples: Milli = $\frac{1}{1000}$, Centi = $\frac{1}{100}$, Deci = $\frac{1}{10}$, Deca = 10, Hecto = 100, Kilo = 1000, Myria = 10,000.

Metric and English Equivalent Measures

MEASURES OF LENGTH

Metric		*English*
1 meter	=	39.37 inches, or 3.28083 feet, or 1.09361 yards
.3048 meter	=	1 foot
1 centimeter	=	.3937 inch
2.54 centimeters	=	1 inch
1 millimeter	=	.03937 inch, or nearly 1-25 inch
25.4 millimeters	=	1 inch
1 kilometer	=	1093.61 yards, or 0.62137 mile

MEASURES OF WEIGHT

Metric		*English*
1 gram	=	15.432 grains
.0648 gram	=	1 grain
28.35 grams	=	1 ounce avoirdupois
1 kilogram	=	2.2046 pounds
4536 kilogram	=	1 pound
1 metric ton 1000 kilograms	=	.9842 ton of 2240 pounds 19.68 cwt. 2204.6 pounds
1.016 metric tons 1016 kilograms	=	1 ton of 2240 pounds

MEASURES OF CAPACITY

Metric		*English*
1 liter (= 1 cubic decimeter)	=	61.023 cubic inches .03531 cubic foot .2642 gal. (American) 2.202 lbs. of water at 62° F.
28.317 liters	=	1 cubic foot
3.785 liters	=	1 gallon (American)
4.543 liters	=	1 gallon (Imperial)

English Conversion Table

Length				
Inches	×	.0833	=	feet
Inches	×	.02778	=	yards
Inches	×	.00001578	=	miles
Feet	×	.3333	=	yards
Feet	×	.0001894	=	miles
Yards	×	36.00	=	inches
Yards	×	3.00	=	feet
Yards	×	.0005681	=	miles
Miles	×	63360.00	=	inches
Miles	×	5280.00	=	feet
Miles	×	1760.00	=	yards
Circumference of circle	×	.3188	=	diameter
Diameter of circle	×	3.1416	=	circumference
Area				
Square inches	×	.00694	=	square feet
Square inches	×	.0007716	=	square yards
Square feet	×	144.00	=	square inches
Square feet	×	.11111	=	square yards
Square yards	×	1296.00	=	square inches
Square yards	×	9.00	=	square feet
Dia. of circle squared	×	.7854	=	area
Dia. of sphere squared	×	3.1416	=	surface
Volume				
Cubic inches	×	.0005787	=	cubic feet
Cubic inches	×	.00002143	=	cubic yards
Cubic inches	×	.004329	=	U. S. gallons
Cubic feet	×	1728.00	=	cubic inches
Cubic feet	×	.03704	=	cubic yards
Cubic feet	×	7.4805	=	U. S. gallons
Cubic yards	×	46656.00	=	cubic inches
Cubic yards	×	27.00	=	cubic feet
Dia. of sphere cubed	×	.5236	=	volume
Weight				
Grains (avoirdupois)	×	.002286	=	ounces
Ounces (avoirdupois)	×	.0625	=	pounds
Ounces (avoirdupois)	×	.00003125	=	tons
Pounds (avoirdupois)	×	16.00	=	ounces
Pounds (avoirdupois)	×	.01	=	hundredweight
Pounds (avoirdupois)	×	.0005	=	tons
Tons (avoirdupois)	×	32000 00	=	ounces
Tons (avoirdupois)	×	2000.00	=	pounds

Tables and Data

English Conversion Table

Energy

Horsepower	×	33000.	=ft.-lbs. per min.
B. t. u.	×	778.26	=ft.-lbs.
Ton of refrigeration	×	200.	=B. t. u. per min.

Pressure

Lbs. per sq. in.	×	2.31	= ft. of water (60°F.)
Ft .of water (60°F.)	×	.433	= lbs. per sq. in.
Ins. of water (60°F.)	×	.0361	= lbs. per sq. in.
Lbs. per sq. in.	×	27.70	= ins. of water (60°F.)
Lbs. per sq. in.	×	2.041	= ins. of Hg. (60°F.)
Ins. of Hg (60°F.)	×	.490	= lbs. per sq. in.

Power

Horsepower	×	746.	= watts
Watts	×	.001341	= horsepower
Horsepower	×	42.4	= B. t. u. per min.

Water Factors (at point of greatest density—39.2°F)

Miners inch (of water)	×	8.976	= U. S .gals. per min.
Cubic inches (of water)	×	.57798	= ounces
Cubic inches (of water)	×	.036124	= pounds
Cubic inches (of water)	×	.004329	= U. S. gallons
Cubic inches (of water)	×	.003607	= English gallons
Cubic feet (of water)	×	62.425	= pounds
Cubic feet (of water)	×	.03121	= tons
Cubic feet (of water)	×	7.4805	= U. S. gallons
Cubic feet (of water)	×	6.232	= English gallons
Cubic foot of ice	×	57.2	= pounds
Ounces (of water)	×	1.73	= cubic inches
Pounds (of water)	×	26.68	= cubic inches
Pounds (of water)	×	.01602	= cubic feet
Pounds (of water)	×	.1198	= U. S. gallons
Pounds (of water)	×	.0998	= English gallons
Tons (of water)	×	32.04	= cubic feet
Tons (of water)	×	239.6	= U. S. gallons
Tons (of water)	×	199.6	= English gallons
U. S. gallons	×	231.00	= cubic inches
U. S. gallons	×	.13368	= cubic feet
U. S. gallons	×	8.345	= pounds
U. S. gallons	×	.8327	= English gallons
U. S. gallons	×	3.785	= liters
English gallons (Imperial)	×	277.41	= cubic inches
English gallons (Imperial)	×	.1605	= cubic feet
English gallons (Imperial)	×	10.02	= pounds
English gallons (Imperial)	×	1.201	= U. S. gallons
English gallons (Imperial)	×	4.546	= liters

Metric Conversion Table

Length

Millimeters	×	.03937	= inches
Millimeters	÷	25.4	= inches
Centimeters	×	.3937	= inches
Centimeters	÷	2.54	= inches
Meters	×	39.37	= inches (Act. Cong.)
Meters	×	3.281	= feet
Meters	×	1.0936	= yards
Kilometers	×	.6214	= miles
Kilometers	÷	1.6093	= miles
Kilometers	×	3280.8	= feet

Area

Sq. Millimeters	×	.00155	= sq. in.
Sq. Millimeters	÷	645.2	= sq. in.
Sq. Centimeters	×	.155	= sq. in.
Sq. Centimeters	÷	6.452	= sq. in.
Sq. Meters	×	10.764	= sq. ft.
Sq. Kilometers	×	247.1	= acres
Hectares	×	2.471	= acres

Volume

Cu. Centimeters	÷	16.387	= cu. in.
Cu. Centimeters	÷	3.69	= fl. drs. (U.S.P.)
Cu. Centimeters	÷	29.57	= fl. oz. (U.S.P.)
Cu. Meters	×	35.314	= cu. ft.
Cu. Meters	×	1.308	= cu. yards
Cu. Meters	×	264.2	= gals. (231 cu. in.)
Litres	×	61.023	= cu. in. (Act. Cong.)
Litres	×	33.82	= fl. oz. (U.S.P.)
Litres	×	.2642	= gals. (231 cu. in.)
Litres	÷	3.785	= gals. (231 cu. in.)
Litres	÷	28.317	= cu. ft.
Hectolitres	×	3.531	= cu. ft.
Hectolitres	×	2.838	= bu. (2150.42 cu. in.)
Hectolitres	×	.1308	= cu. yds.
Hectolitres	×	26.42	= gals. (231 cu. in.)

Weight

Grams	×	15.432	= grains (Act. Cong.)
Grams	÷	981.	= dynes
Grams (water)	÷	29.57	= fl. oz.
Grams	÷	28.35	= oz. avoirdupois
Kilo-grams	×	2.2046	= lbs.

Metric Conversion Table (Cont.)

Weight

Kilo-grams	×	35.27	= oz. avoirdupois
Kilo-grams	×	.0011023	= tons (2000 lbs.)
Tonneau (Metric ton)	×	1.1023	= tons (2000 lbs.)
Tonneau (Metric ton)	×	2204.6	= lbs.

Unit Weight

Grams per cu. cent.	÷	27.68	= lbs. per cu. in.
Kilo per meter	×	.672	= lbs. per ft.
Kilo per cu. meter	×	.06243	= lbs per cu. ft.
Kilo per Cheval	×	2 235	= lbs per h. p.
Grams per liter	×	.06243	= lbs. per cu. ft.

Pressure

Kilo-grams per sq. cm.	×	14 223	= lbs. per sq. in.
Kilo-grams per sq. cm.	×	32 843	= ft. of water (60°F.)
Atmospheres (international)	×	14 696	= lbs. per sq. in

Energy

Joule	×	.7376	= ft. lbs.
Kilo-gram meters	×	7.233	= ft. lbs.

Power

Cheval vapeur	×	.9863	= h. p.
Kilo-watts	×	1 341	= h. p.
Watts	÷	746	= h. p.
Watts	×	.7373	= ft. lbs. per sec

Miscellaneous

Kilogram calorie	×	3.968	= B. t. u.
Standard gravity (Sea level 45° lat.)	÷	980.665	= centimeters per sec per sec.
Frigories/hr. (French)	÷	3023.9	= Tons refrigeration

Tables and Data

e following pages show temperatures on Fahrenheit and Centigrade thermometers.

Equivalent Temperature Readings for Fahrenheit and Centigrade Scales

hren- eit gs.	Centigrade Degs.	Fahrenheit Degs.	Centigrade Degs.	Fahrenheit Degs.	Centigrade Degs.	Fahrenheit Degs.	Centigrade Degs.
59.4	—273	—21.	—29.4	17.6	—8.	56.	13.3
436.	—270.	—20.2	—29.	18.	—7.8	57.	13.9
18.	—260.	—20.	—28.9	19.	—7.2	57.2	14.
00.	—240.	—19.	—28.3	19.4	—7.	58.	14.4
-382.	—230.	—18.4	—28.	20.	—6.7	59.	15.
-364.	—220.	—18.	—27.8	21.	—6.1	60.	15.6
-346.	—210.	—17.	—27.2	21.2	—6.	60.8	16.
-328.	—200.	—16 6	—27.	22.	—5.6	61.	16.1
-310.	—190.	—16.	—26 7	23.	—5.	62.	16.7
-292.	—180.	—15.	—26.1	24.	—4.4	62.6	17.
-274.	—170.	—14.8	—26.	24.8	—4.	63.	17.2
256.	—160.	—14.	—25.6	25.	—3.9	64.	17.8
-238.	—150.	—13.	—25.	26.	—3 3	64.4	18.
220.	—140	—12.	—24.4	26.6	—3.	65.	18.3
202.	—130.	—11.2	—24.	27.	—2 8	66.	18.9
-184.	—120.	—11.	—23.9	28.	—2.2	66.2	19.
-166.	—110	—10.	—23.3	28.4	—2.	67.	19.4
—148.	—100.	— 9 4	—23.	29.	—1.7	68.	20.
—139.	— 95.	— 9.	—22.8	30.	—1.1	69.	20.6
—130.	— 90.	— 8.	—22.2	30.2	—1.	69.8	21.
—121.	— 85.	— 7.6	—22.	31.	—0.6	70.	21.1
—112	— 80.	— 7.	—21.7	32.	0.	71.	21.7
—103.	— 75	— 6.	—21.1	33.	+0.6	71.6	22.
— 94.	— 70.	— 5.8	—21.	33.8	1.	72.	22.2
— 85.	— 65.	— 5.	—20.6	34.	1.1	73.	22.8
— 76.	— 60.	— 4.	—20.	35.	1.7	73.4	23.
— 67.	— 55.	— 3.	—19.4	35.6	2.	74.	23.3
— 58.	— 50.	— 2.2	—19.	36.	2.2	75.	23.9
— 49.	— 45.	— 2.	—18.9	37.	2 8	75.2	24.
— 40.	— 40.	— 1.	—18.3	37.4	3.	76.	24.4
— 39.	— 39 4	— 0.4	—18.	38.	3.3	77.	25.
— 38.2	— 39.	0.	—17.8	39.	3 9	78.	25.6
— 38.	— 38.9	+ 1.	—17.2	39.2	4.	78.8	26.
— 37.	— 38.3	1.4	—17.	40.	4.4	79.	26.1
— 36.4	— 38.	2.	—16.7	41.	5.	80.	26.7
— 36.	— 37.8	3.	—16.1	42.	5.6	80.6	27.
— 35.	— 37.2	3.2	—16.	42.8	6.	81.	27.2
— 34.6	— 37.	4.	—15.6	43.	6.1	82.	27.8
— 34.	— 36 7	5.	—15.	44.	6 7	82.4	28.
— 33.	— 36.1	6.	—14.4	44.6	7.	83.	28.3
— 32.8	— 36.	6.8	—14.	45.	7.2	84.	28.9
— 32.	— 35.6	7.	—13 9	46.	7.8	84.2	29.
— 31.	— 35.	8.	—13.3	46.4	8.	85.	29.4
— 30.	— 34.4	8.6	—13.	47.	8.3	86.	30.
— 29.2	— 34.	9.	—12.8	48.	8.9	87.	30 6
— 29.	— 33.9	10.	—12.2	48.2	9.	87.8	31.
— 28.	— 33.3	10.4	—12.	49.	9.4	88.	31.1
— 27.4	— 33.	11.	—11.7	50.	10.	89.	31.7
— 27.	— 32.8	12.	—11.1	51.	10.6	89.6	32.
— 26.	— 32 2	12.2	—11.	51.8	11.	90.	32.2
— 25.6	— 32.	13.	—10.6	52.	11.1	91.	32.8
— 25.	— 31.7	14.	—10.	53.	11.7	91.4	33.
— 24.	— 31.1	15.	— 9.4	53.6	12.	92.	33.3
— 23.8	— 31.	15.8	— 9.	54.	12.2	93.	33.9
— 23.	— 30.6	16.	— 8.9	55.	12.8	93.2	34.
— 22.	— 30.	17.	— 8.3	55.4	13.	94.	34.4

Equivalent Temperature Readings for Fahrenheit and Centigrade Scales

Fahrenheit Degs.	Centigrade Degs.	Fahrenheit Degs.	Centigrade Degs.	Fahrenheit Degs.	Centigrade Degs.	Fahrenheit Degs.	Centigrade Degs.
95.	35.	134.	56.7	172.4	78.	211.	99.4
96.	35.6	134.6	57.	173.	78.3	212.	100.
96.8	36.	135.	57.2	174.	78.9	213.	100.6
97.	36.1	136.	57.8	174.2	79.	213.8	101.
98.	36.7	136.4	58.	175.	79.4	214.	101.1
98.6	37.	137.	58.3	176.	80.	215.	101.7
99.	37.2	138.	58.9	177.	80.6	215.6	102.
100.	37.8	138.2	59.	177.8	81.	216.	102.2
100.4	38.	139.	59.4	178.	81.1	217.	102.8
101.	38.3	140.	60.	179.	81.7	217.4	103.
102.	38.9	141.	60.6	179.6	82.	218.	103.3
102.2	39.	141.8	61.	180.	82.2	219.	103.9
103.	39.4	142.	61.1	181.	82.8	219.2	104.
104.	40.	143.	61.7	181.4	83.	220.	104.4
105.	40.6	143.6	62.	182.	83.3	221.	105.
105.8	41.	144.	62.2	183.	83.9	222.	105.6
106.	41.1	145.	62.8	183.2	84.	222.8	106.
107.	41.7	145.4	63.	184.	84.4	223.	106.1
107.6	42.	146.	63.3	185.	85.	224.	106.7
108.	42.2	147.	63.9	186.	85.6	224.6	107.
109.	42.8	147.2	64.	186.8	86.	225.	107.2
109.4	43.	148.	64.4	187.	86.1	226.	107.8
110.	43.3	149.	65.	188.	86.7	226.4	108.
111.	43.9	150.	65.6	188.6	87.	227.	108.3
111.2	44.	150.8	66.	189.	87.2	228.	108.9
112.	44.4	151.	66.1	190.	87.8	228.2	109.
113.	45.	152.	66.7	190.4	88.	229.	109.4
114.	45.6	152.6	67.	191.	88.3	230.	110.
114.8	46.	153.	67.2	192.	88.9	231.	110.6
115.	46.1	154.	67.8	192.2	89.	231.8	111.
116.	46.7	154.4	68.	193.	89.4	232.	111.1
116.6	47.	155.	68.3	194.	90.	233.	111.7
117.	47.2	156.	68.9	195.	90.6	233.6	112.
118.	47.8	156.2	69.	195.8	91.	234.	112.2
118.4	48.	157.	69.4	196.	91.1	235.	112
119.	48.3	158.	70.	197.	91.7	235.4	[illegible]
120.	48.9	159.	70.6	197.6	92.	236.	[illegible]
120.2	49.	159.8	71.	198.	92.2	237.	[illegible]
121.	49.4	160.	71.1	199.	92.8	237	[illegible]
122.	50.	161.	71.7	199.4	93.	238.	[illegible]
123.	50.6	161.6	72.	200.	93.3	239.	[illegible]
123.8	51.	162.	72.2	201.	93.9	240.	[illegible]
124.	51.1	163.	72.8	201.2	94.	240.8	116.
125.	51.7	163.4	73.	202.	94.4	241.	[illegible]
125.6	52.	164.	73.3	203.	95.	242.	[illegible]
126.	52.2	165.	73.9	204.	95.6	242.6	117.
127.	52.8	165.2	74.	204.8	96.	243.	117.
127.4	53.	166.	74.4	205.	96.1	244.	117.8
128.	53.3	167.	75.	206.	96.7	244.4	118.
129.	53.9	168.	75.6	206.6	97.	245.	118.3
129.2	54.	168.8	76.	207.	97.2	246.	118.9
130.	54.4	169.	76.1	208.	97.8	246.2	119.
131.	55.	170.	76.7	208.4	98.	247.	119.4
132.	55.6	170.6	77.	209.	98.3	248.	120.
132.8	56.	171.	77.2	210.	98.9	249.	120.6
133.	56.1	172.	77.8	210.2	99.	249.8	121.